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Vulnerability and Lethality Testing System (VALTS)

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AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
EGLIN AIR FORCE BASE, FLORIDA

VULNERABILITY AND LETHALITY TESTING SYSTEM (VALTS)

Sidney O. Shelley

FOREWORD

This report has been prepared in response to Project Directive 8780V018. Development of the Vulnerability and Lethality Testing System (VALTS) began in 1967 and the systems were declared operational in 1971. Development of a facility such as the VALTS is a continuing process; therefore, this report should be considered an interim document.

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ABSTRACT

This report describes the Vulnerability and Lethality Testing System (VALTS) at the Armament Development and Test Center, Eglin Air Force Base, Florida. The VALTS is a fully electronic, high-speed automatic data acquisition system for measuring fragment velocities, fragment dispersion, blast pressure-front velocities, and pressure profiles resulting from statically detonated explosives. The system collects a large quantity of accurately measured data thus substantially reducing the number of test missions required to evaluate the effectiveness of munitions. The VALTS data are reduced in the Center Computer Sciences Laboratory by means of a CDC 6600 computer and ancillary equipment. Three tests sites on the Eglin reservation contain VALTS equipment. This report contains a technical description of the VALTS equipment and the techniques employed in data collection.

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SECTION I

INTRODUCTION

The Vulnerability and Lethality Testing System (VALTS) at the Armament Development and Test Center (ADTC), Eglin Air Force Base, Florida, is a modern, three-site facility featuring fully electronic, high-speed automatic data acquisition systems for evaluating the effectiveness of explosive munitions. The data collected yield accurate reliable measurements of fragment velocity and dispersion, blast-pressure-front velocity, and blast pressure profiles that result from statically detonated explosives. Collected data are reduced in the ADTC Computer Sciences Laboratory by the CDC 6600 computer system. The format of the reduced data is designed for rapid and easy analysis of test results.

The VALTS at the ADTC replaces a flash-panel photographic data collection system. The two systems were tested simultaneously against a common standard. Documented test results[1] revealed that, for single-shot tests, fragment velocities measured with the VALTS were accurate to within 1 percent whereas the flash-panel system measurements were, on the average, about 7 percent accurate. On multiple fragment tests, the VALTS recovered a greater percentage of data than the flash-panel system at every test radius. The test report concluded that the VALTS should be the primary data collection system. The report also pointed out that the flash-panel system requires a tedious manual readout of photographic data and accuracies are dependent upon the judgement of the human film reader whereas the VALTS data are digitized for rapid computer processing and therefore are not subject to human error.

[1] Technical Report ADTC-TR-72-76, A Comparison Test and Analysis of Two Fragment Velocity Measuring Systems, August 1972, Unclassified, AD 903 263L.

SECTION II

GENERAL DESCRIPTION

FACILITY DESCRIPTION

The ADTC has equipped three sites on Test Area C-80[2] with VALTS data acquisition systems. Each site contains a test arena for detonating explosives and an operations building that houses data acquisition equipment. Site C-80A, the smallest facility, can support tests of munitions having explosive charges weighing up to 200 pounds; Site C-80B can handle explosive charges weighing up to 500 pounds; Site C-80C can accommodate explosive charges up to 3,000 pounds. All sites are equipped for collecting fragment velocity data, fragment dispersion data, and pressure-front velocity data. Sites C-80A and C-80C are also equipped for collecting blast pressure profile data; Site C-80B lacks instrumentation for collecting profile data.

Figure 1 presents a typical array of sensor screens mounted in a semicircle around an explosive test item at Site C-80. The operations building at Site C-80 (Figure 2), located near the test arena, is bunkered to protect personnel and equipment. Figure 3 shows the data acquisition equipment in the operations building at Site C-80A. The control console at Site C-80A is shown in Figure 4. The facilities depicted in Figures 1 through 4 are typical of all three sites.

The VALTS also includes a fabrication shop where sensor screens, transducer mounts and stands, and miscellaneous items of equipment are tailor-made for specific test requirements. The shop is located on the C-80 test range relatively close to the three test sites. Sensor screen construction is described in Section III.

VALTS DATA SYSTEM

The VALTS uses two basic methods for acquiring and processing data. Figure 5 is a block diagram illustrating the procedure for collecting and processing fragment velocity and pressure-front velocity data. In this

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[2] ADTC Technical Facilities, Volume II, Land Test Areas, August 1971, Unclassified, AD 890 744.

method, a high-speed magnetic core memory collects and stores data from as many as 72 sensors simultaneously in 8,192 words or locations. The data collected in the memory are digital and, after the mission is completed, are read out of the memory onto digital tape in a format suitable for computer reduction in the Computer Sciences Laboratory.

The technique for collecting and processing pressure profile data is illustrated in Figure 6. The pressure-profile transducers develop an output voltage which is proportional to the shock wave amplitude in pounds per square inch. Since the voltage is analog, the data are recorded on analog tape. Shortly before each mission, a precise 16-step calibration waveform is recorded on each data channel of the tape. After the mission, the calibration signal and profile data are digitized and read into the magnetic core memory. The digitized data are then read out of the memory onto magnetic tape for transmittal to the Computer Sciences Laboratory.

The VALTS can collect data using the two methods simultaneously because the methods employ different collection equipment. Normally, data are not collected using both methods at the same time because each method requires a special arrangement of sensors or transducers according to the test item. For fragment velocity measurements, the sensor screens are placed at a relatively long radius from the explosive to insure that the shock wave, which slows at a faster rate than fragments, will arrive too late to disturb fragment measurements. Because of the relatively long radius, sensor screens are mounted at the same height above the ground as the test munition. In making pressure profile measurements, a major concern is to avoid shock wave reflections from the ground; therefore, the test item is elevated above the ground as far as is practical and the transducers are placed at a short ground radius from the test item.

To prevent fragments from bouncing off the ground into a sensor screen, a semicircular mound of earth is constructed in front of the screens. Fragments striking the ground in front of the mound ricochet off the mound with a trajectory sufficiently high to clear the top of the sensor screens. The mound also protects sensor cables from damage caused by low traveling fragments.

Appendices I through IV contain detailed descriptions of VALTS equipment and data reduction.

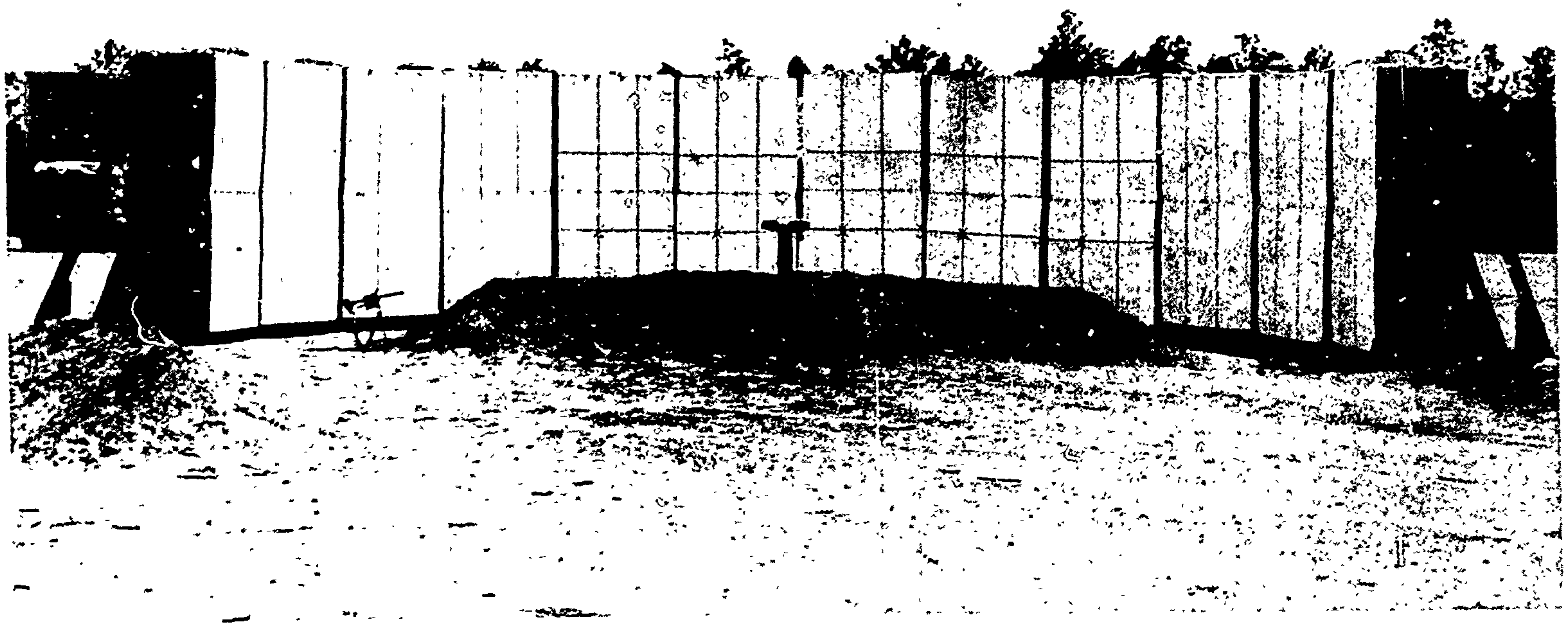


Figure 1. Test arena, Site C-80, showing a typical sensor screen array

Figure 2. Operations building, Site C-80

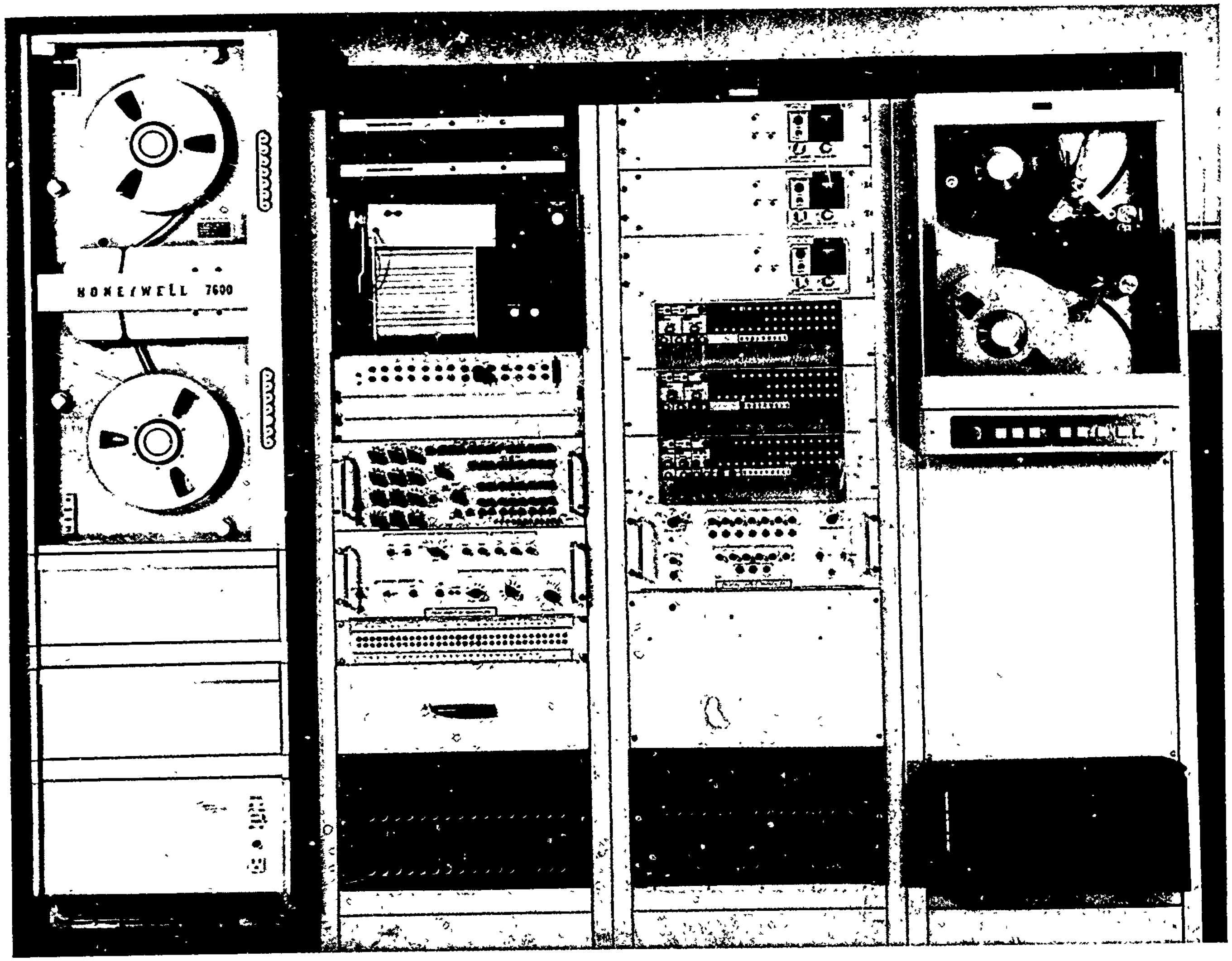


Figure 3. VALTS data acquisition equipment

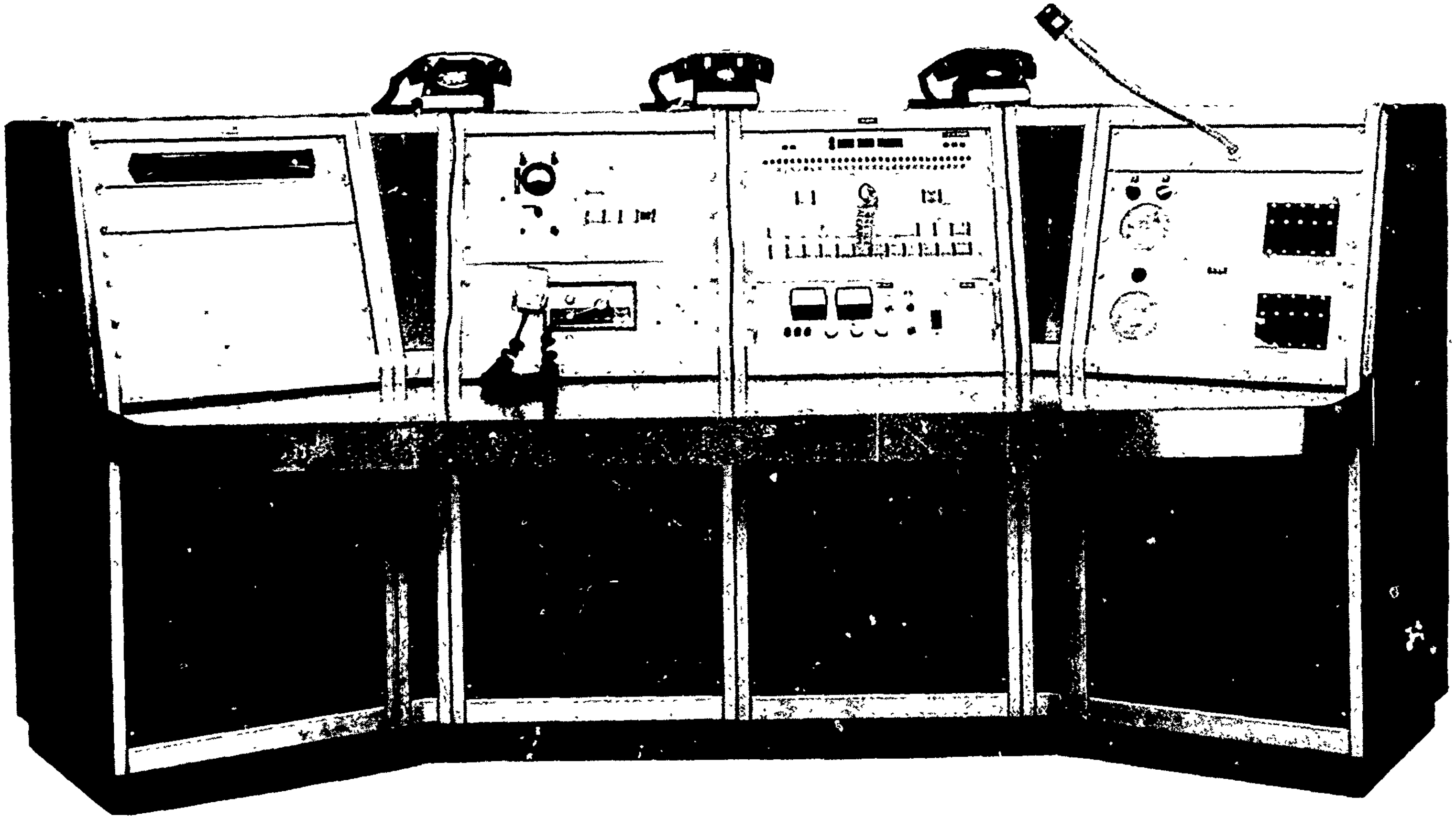


Figure 4. VALTS control console

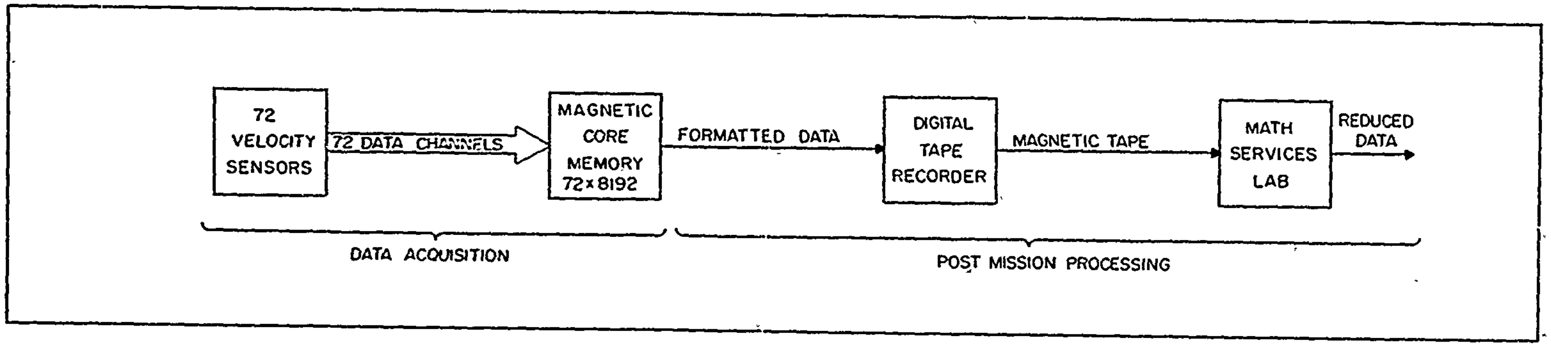


Figure 5. Block diagram of fragment velocity and pressure-front velocity data system

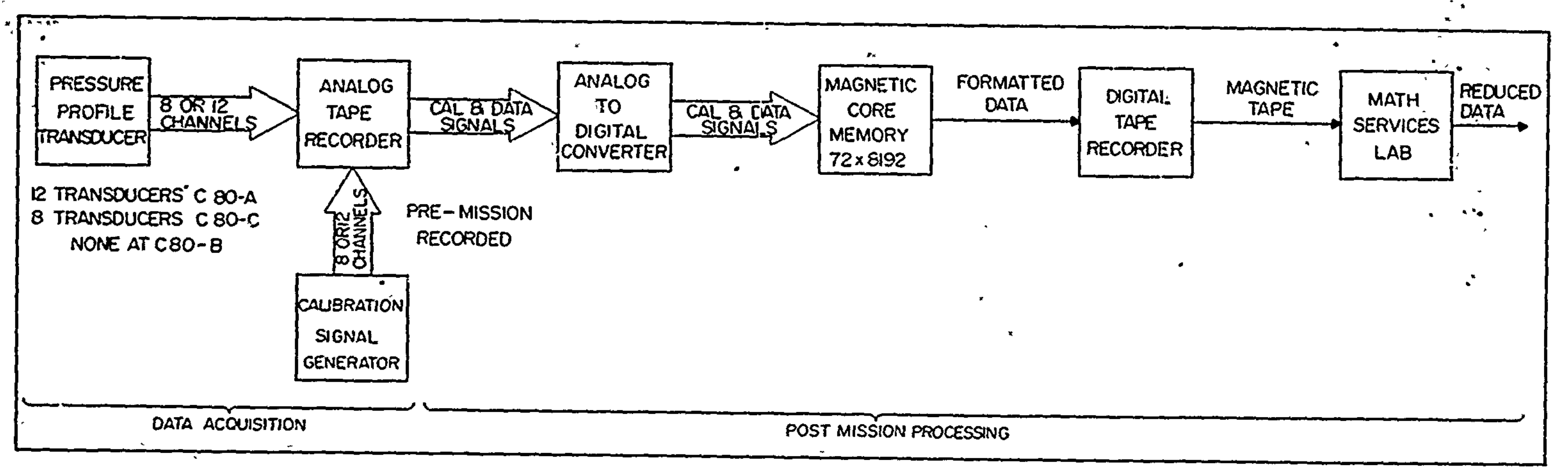


Figure 6. Block diagram of pressure profile data system

SECTION III.

FRAGMENT VELOCITY AND DISPERSION MEASUREMENTS

FRAGMENT VELOCITY DATA COLLECTION

The fragment velocity data system measures the time of fragment travel from an explosive over a known distance to a sensor screen. Sensor screens are normally arranged in a semicircle around the explosive as shown in Figure 1. The radius, which is carefully measured, depends upon the type and size of the munition. At each site, the system can collect data from up to 72 sensor screens simultaneously. Figure 7 presents a block diagram showing the data collection channel for one sensor screen. Two light-sensitive detectors close to the munition detect the time of detonation, T_0, or "first-light" as that time is normally called, and deliver an enable signal to the address controller in the operations building. (Two T_0 detectors are used to prevent loss of data in case one of the detectors fails.)

At time T_0 or after a programed delay, the data system begins reading data into a high-speed digital storage magnetic core memory. The core memory, consisting of three Honeywell ICM-40, 24-bit memories wired in parallel, has a total capacity of 72 bits in 8,192 locations or words. In response to the address controller, the memory cycles one word at a time and records a logic 0 data bit in each word until a fragment penetrates the sensor screen. The fragment, being a good conductor of electricity, completes a circuit from one surface of the screen to the other. This action delivers a signal to the data system which is recorded into the memory as a logic 1 data bit. As the memory cycling rate is known, the location of the logic 1 data bit in the memory defines the fragment travel time. After the mission, the data are read out of the core memory onto magnetic tape which is reduced by computer at the Computer Sciences Laboratory.

The discussion in the two preceding paragraphs was purposely simplified to bring out the basic concept of fragment velocity measurement. The data acquisition system measures fragment travel time over a known distance. The computer calculates the fragment velocity which is, of course, the average velocity of the fragment over the known distance.

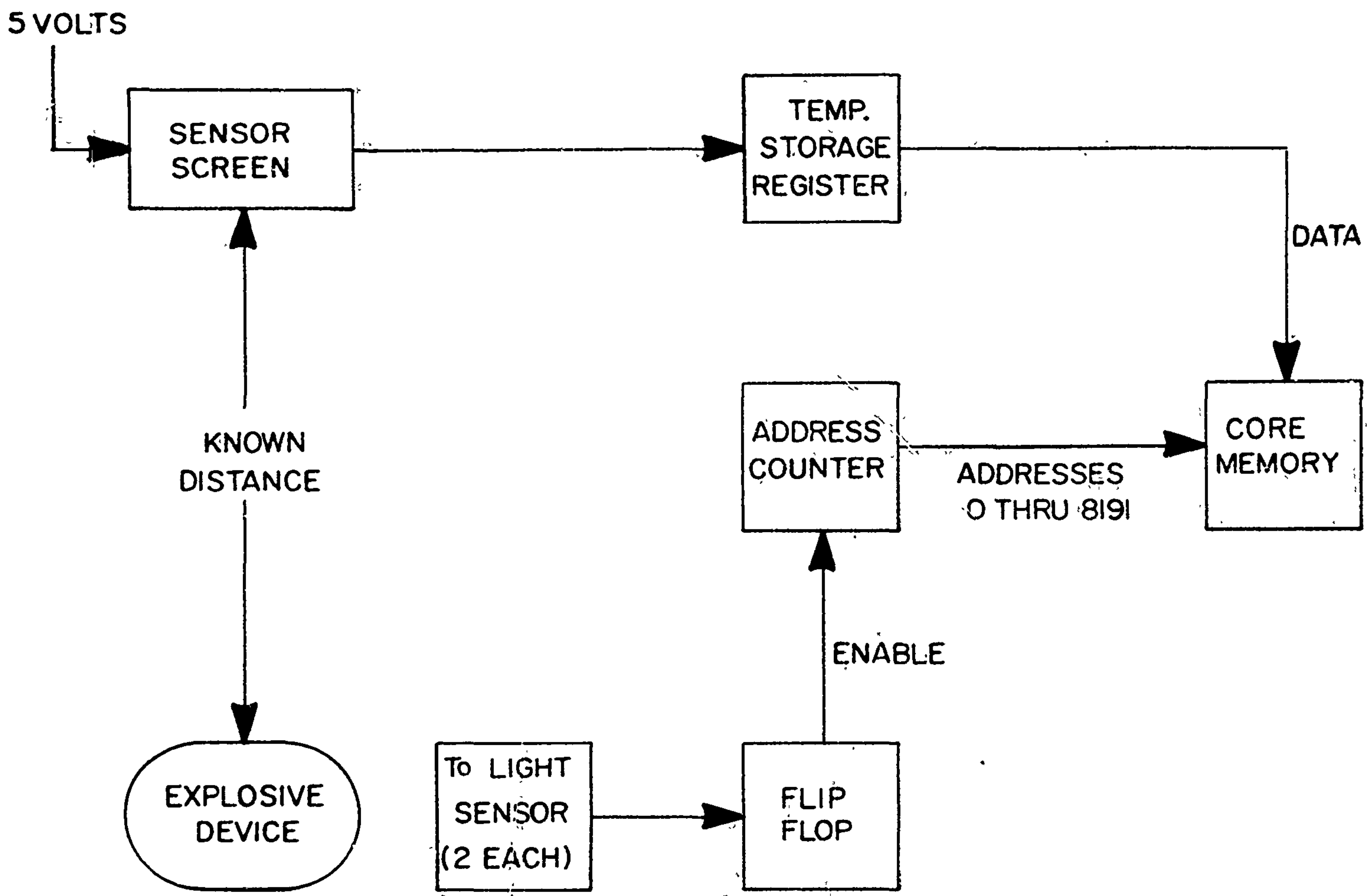


Figure 7. Block diagram of fragment velocity measurement system

The VALTS measures fragment travel time quite accurately. The system uses a precise crystal oscillator as a master clock to control the cycling rates of the magnetic core memory. At Sites C-80A and C-80C the master clock frequency is 1.2 MHz. This clock, with a divide-by-two circuit, cycles the memory at a rate of 600 kHz. At this rate (system maximum) data are recorded into memory at 1.67-microsecond intervals. With this time resolution, time measurements are 99.90 to 99.98 percent accurate.

At the maximum cycling rate of 600 kHz, the memory would cycle through its 8,192 words in 13.7 milliseconds; consequently, with a large arena radius, the memory would finish cycling before slow fragments hit the sensor screens. To prevent the loss of slow-fragment data, the memory can be programed in advance to start cycling from 1 to 7 milliseconds after time T_0 and can also be programed to reduce the cycling rate two times during the course of the mission; first to 300 kHz and then to 150 kHz. The memory cycling rates cited apply to Sites C-80A and C-80C. At these sites, the memory can also cycle at 300, 150, and 75 kHz in sequence. The cycling rates available at the three sites are presented in Table I.

Table I. Memory cycling rates

Rate	Cycling rate (kHz)				
	Site C-80A			Site C-80C	
	Fast	Slow	Site C-80B	Fast	Slow
1	600	300	450.0	600	300
2	300	150	225.0	300	150
3	150	75	112.5	150	75

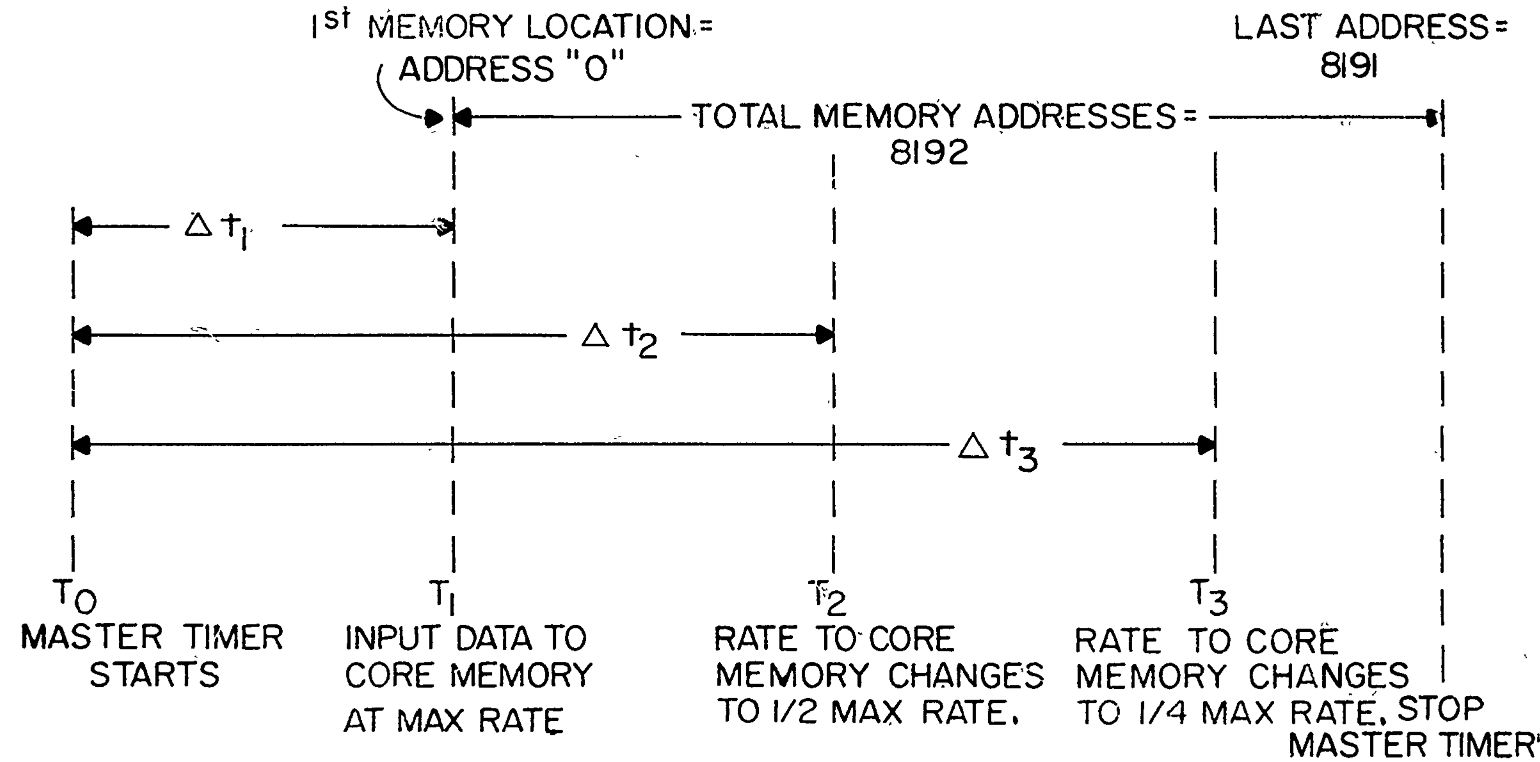
At Site C-80B, the master clock frequency is 900 kHz, from which the rates for that site are derived. The slow rates at Sites C-80A and C-80C are obtained by adding an extra divide-by-two flip-flop after the 1.2-MHz clock. Regardless of master clock frequency, the second rate is one-half the first and the third rate is one-half the second.

The times at which the cycling rates change are switch-selectable (Figure 8). The first switch determines the delay time (ΔT_1) between detonation and the start of the memory cycling at time T_1. At time T_1 the memory begins cycling at the maximum rate and continues at that rate until time T_2 when the rate becomes one-half the maximum. The rate changes again at time T_3 to one-fourth the maximum rate and continues at that rate until the memory completes the cycling at address 8,191. If the first rate switch is set for minimum delay, the rate 2 and rate 3 circuits are disabled which allows the memory to cycle through all 8,192 words at the fast rate. A modification to the system (not shown on Figure 8) allows the memory to start cycling at time T_0 in which case the cycling rate is maximum from start to finish.

The various choices of memory cycling rates and delays provide a range of sampling times that extend from a minimum of 13.7 milliseconds after the detonation to slightly more than 100 milliseconds after T_0. The choices enable the munition tester to select a rate that will provide optimum data coverage for the type and size of munition being tested. In most cases, fragment velocities, maximum and minimum, can be estimated before a test and the rates and delays can be programed accordingly.

SENSOR SCREEN CONSTRUCTION AND CHARACTERISTICS

TYPES OF SENSOR SCREENS. Electrically, sensor screens are simple devices. All sensor screens, regardless of type, operate on the principle that a fragment passing through a screen creates a signal voltage by completing an electrical circuit between two conducting elements of the screen that are at different potentials. Two basic types of sensor screens have been developed. One type, consisting of two conducting surfaces separated by an insulating material, is known as a Dahlgren screen because its construction is similar to that of screens originally developed by the Naval Weapons Laboratory at Dahlgren, Virginia. The other type of screen has a grid of horizontal conductors equally spaced in the screen and electrically connected so that even-numbered conductors can be at one potential and odd-numbered conductors can be at another. The Dataplex Type K1 and the Brown Engineering Company (BECO) screens are examples of grid screens.



MAX RATE	Δt_1 SELECTABLE	Δt_2 SELECTABLE	Δt_3 SELECTABLE
600 KHZ	1 - 7 MS	4 - 14 MS	8 - 28 MS
450 KHZ	1.3 - 9.3 MS	5.3 - 18.3 MS	10.6 - 36.6 MS
300 KHZ	2 - 14 MS	8 - 24 MS	16 - 56 MS

Figure 8. Core memory data sampling sequence

DAHLGREN SCREENS. Sensor screens of the Dahlgren type are manufactured at the Test Area C-80 Complex. A Dahlgren screen (Figure 9) consists of two conductive surfaces separated by an insulator, usually cardboard. The rear surface is a layer of aluminum foil which is glued to the insulator. The front surface of the insulator is spray-painted with vaporized aluminum which is applied by means of a flame spray gun that uses a flame fueled by acetyline and oxygen to vaporize aluminum wire. Aluminum foil can not be used as the front surface because foil is pushed through the insulating material by the fragment and creates erroneous data due to later vibrational or continuous contact between the surfaces.

Because the Dahlgren screens are constructed locally, their surface dimensions can be any size within reasonable limits. If a large screen surface area is required, two or more sensor screens may be connected electrically in parallel to function as a single screen. On the other hand, small surface screens are usually made by dividing the front surface of a normal screen into subpanels with strips of masking tape applied to the insulator before the screen is painted (Figure 10). The thickness of the insulating material can be varied to either accommodate or discriminate against very small fragments. Figure 9 depicts one of several methods of sensor screen construction. Locally manufactured Dahlgren screens cost less than $1.00 each compared to nearly $7.00 each for the commercially manufactured BECO screens. Because of this saving, Dahlgren screens are used almost exclusively on the Eglin C-80 Text Complex. Dahlgren screens do have some disadvantages, notably a higher capacitance between conductors than BECO screens; however, the cost differential offsets this shortcoming.

BECO SCREENS. A BECO screen (Figure 11) consists of a copper laminated grid network on a mylar screen impregnated with epoxy. Figure 12 illustrates the grid arrangement of the screen. All BECO screens are 20 by 30 inches and are available in four grid spacings: 0.05, 0.09, 0.15, and 0.21 inch. As shown in Figure 12, the center bus is common to both halves of the screen. Several BECO screens can be easily connected in parallel to enlarge the sampling area (window size) of an individual sector. Advantages of the BECO screens are: (1) ease of handling and arena setup, (2) choice of grid spacing, and (3) low capacitance of the screen.

A major disadvantage of a BECO screen is that a fragment passing through the screen cuts the conductors that are hit, preventing them from sensing fragments that arrive later. Furthermore, BECO screens when hit by a fragment have a tendency to fray instead of making a clean hole.

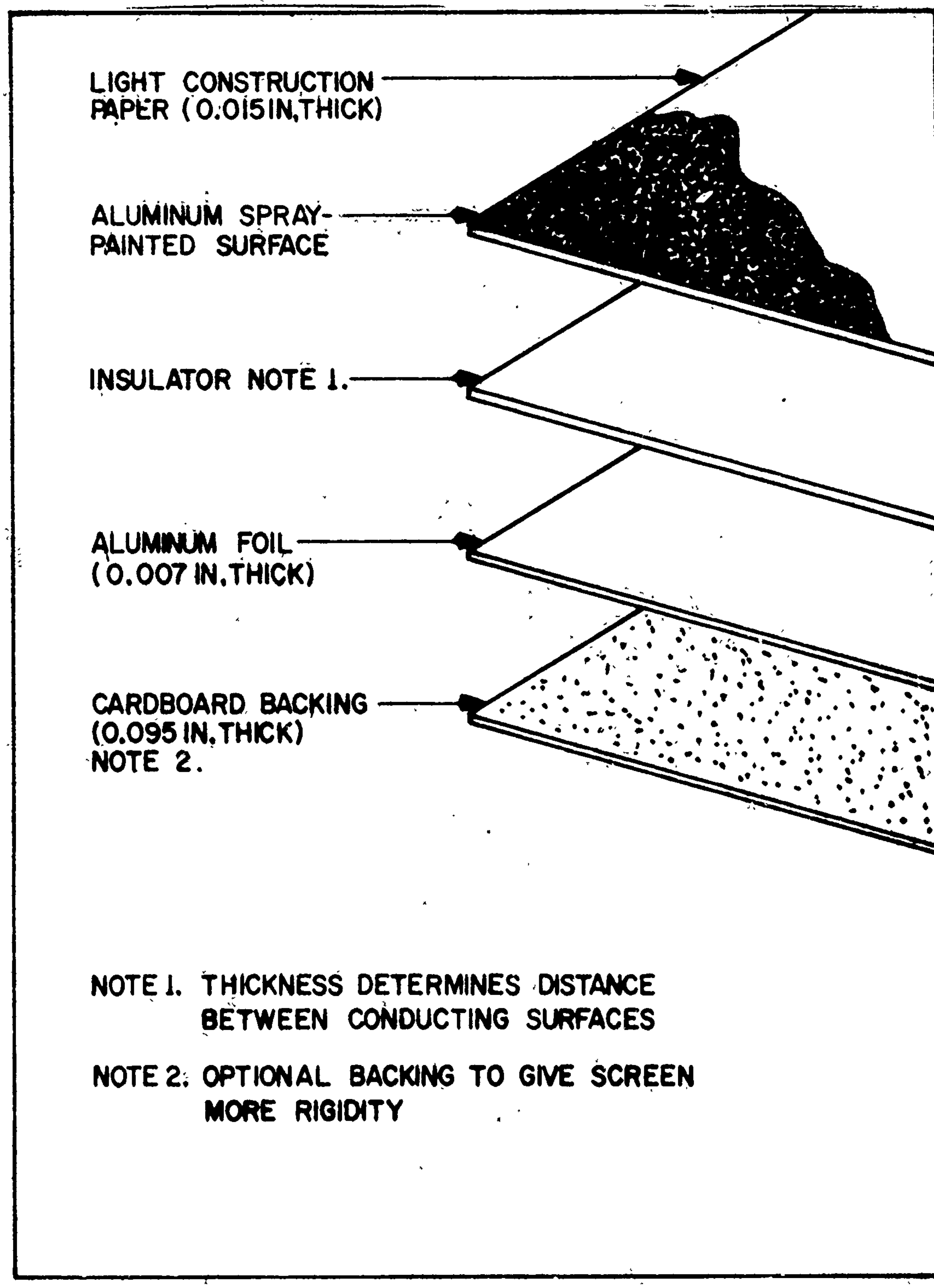


Figure 9. Exploded view of Dahlgren screen

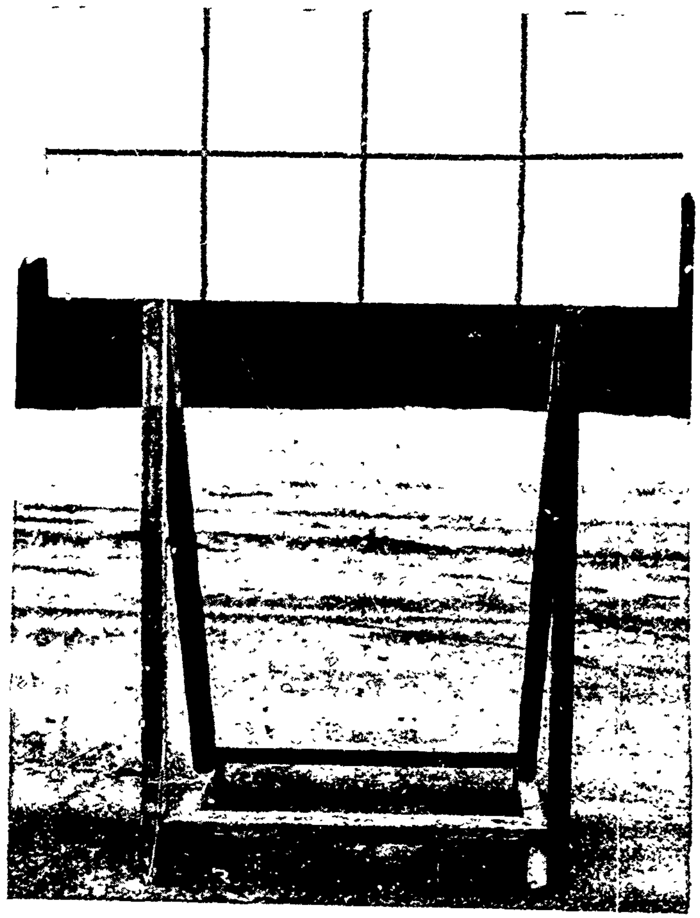


Figure 10. Eight-panel Dahlgren screen

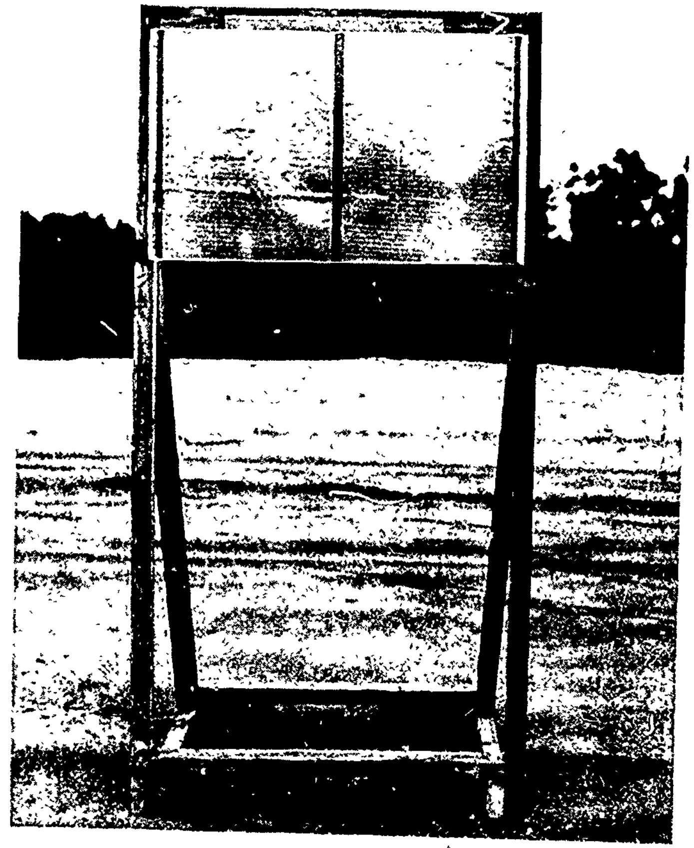


Figure 11. BECO screen

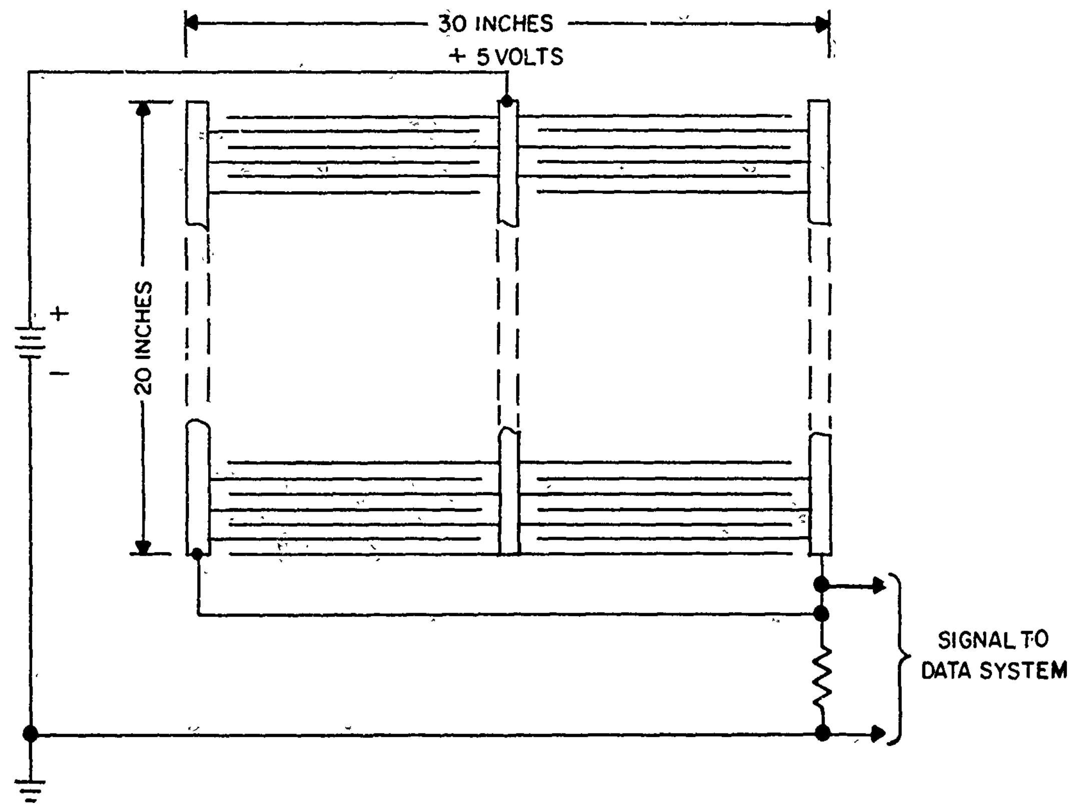


Figure 12. BECO screen construction and operation

Commercial sensor screens, such as the BECO screens, have been used successfully on the VALTS test arenas and could still be used; however, because of the limitations mentioned and the high cost, BECO screens are seldom used on the VALTS test arenas. Dahlgren screens which are more versatile, have fewer drawbacks, and are less expensive are now employed almost exclusively for VALTS testing.

FRAGMENT VELOCITY SIGNAL CONDITIONING

The fragment velocity input circuit shown in Figure 13 conditions the signal that is sensed when a fragment penetrates a sensor screen. The conditioning circuit consists of resistors R1 and R2, cable capacitance, and the capacitance of the conductive surfaces of the sensor screen. The sensor screen, shown as a switch on the figure, applies 5 volts to the circuit when a fragment is in contact with both surfaces of the screen.

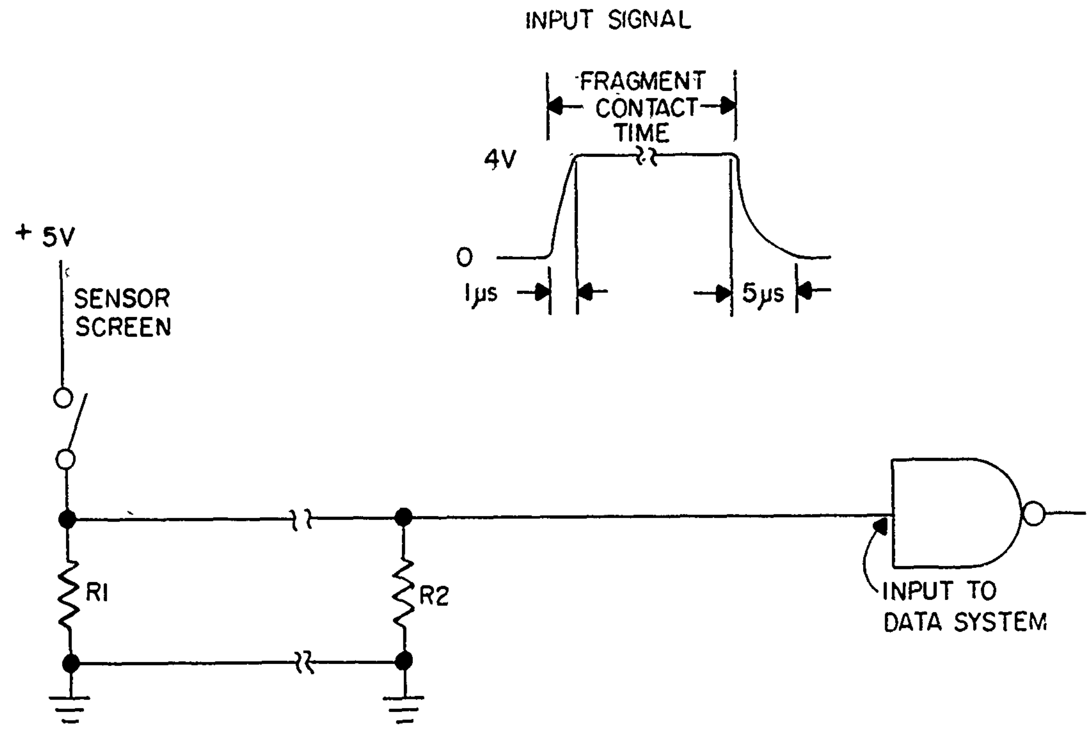


Figure 13. Fragment velocity input circuit and input signal

The conditioned signal, illustrated in the figure, rises to about 4 volts in about 1 microsecond, remains at that level until the fragment loses contact with the front surface of the screen, and then decays to zero in about 5 microseconds. The resistors not only control the characteristics of the conditioned signal but also minimize extraneous noise signals.

The signal conditioning circuit was intentionally designed to produce a long decay time of 5 microseconds. During this time, the memory logic circuit can not reset and therefore continues to read logical 1s into the memory. This feature helps prevent an irregularly shaped fragment from scoring more than one velocity hit in the memory. Irregular fragments sometimes make and break contact with the conducting surfaces of a screen two or more times while passing through the screen. If a fragment loses and then regains contact during the decay time, the break of contact can not be recorded in memory, instead the data appear as a continuous contact by a single fragment.

Some large odd-shaped fragments could recontact the screen surfaces after the decay time; therefore, computer programs have been designed to reject secondary hits. Three computer options are available. One program rejects a secondary hit when only a single logical 0 data bit appears between logical 1s. Another option requires at least two logical 0s between logical 1 data bits to score two separate fragments. The third choice of computer program rejects a secondary hit unless three or more logical 0s separate the logical 1 data bits.

If two or more fragments penetrate a sensor screen simultaneously or nearly so, one of the fragments masks the other allowing the memory to record only a single hit. This masking, known as blind time, and methods of minimizing its effects are discussed in Appendix V.

FRAGMENT VELOCITY DATA TRANSFER TO DIGITAL TAPE

Fragment velocity data that are stored in the ICM-40 core memory during a mission consist of 8,192 words each containing 72 bits. The words (Figure 14) correspond to the address intervals shown on the figure. Since the digital tape contains seven recording tracks, the transfer technique records six data bits at a time, leaving track no. 7 for recording a vertical parity bit. The recording sequence, as controlled by the digital tape recorder, records data bits 1 through 6 in column 1 from address zero sequentially through address 8,191, then switches to the data bits in column 2, and continues in this manner until all columns are recorded on the digital tape. The recording format divides each column into six records of 1,368 characters per record, where a character consists of a set of six data bits and a vertical parity bit (Figure 15). After recording characters zero through 1,367, the format leaves three blank character spaces and then records a longitudinal parity bit on each of the six data tracks. A standard 3/4-inch record gap is made to separate records.

Records 2 through 5 are recorded in the same manner as record 1. Since there are 8,192 words in the core memory, there are just 1,352 data characters remaining in column 1 for recording in record 6. To make record 6 equal in length to the other records, the system logic circuits add 16 all-zero characters to record 6. After the zero characters are recorded, longitudinal parity bits are added for each data track as was done for the first five records. This completes the formatting of column 1 on digital tape. Columns 2 through 12 are then recorded on the tape in the same format as column 1. After column 12 is recorded, at least 3-1/2 inches of blank tape are run off and an end-of-file code is recorded. This code,

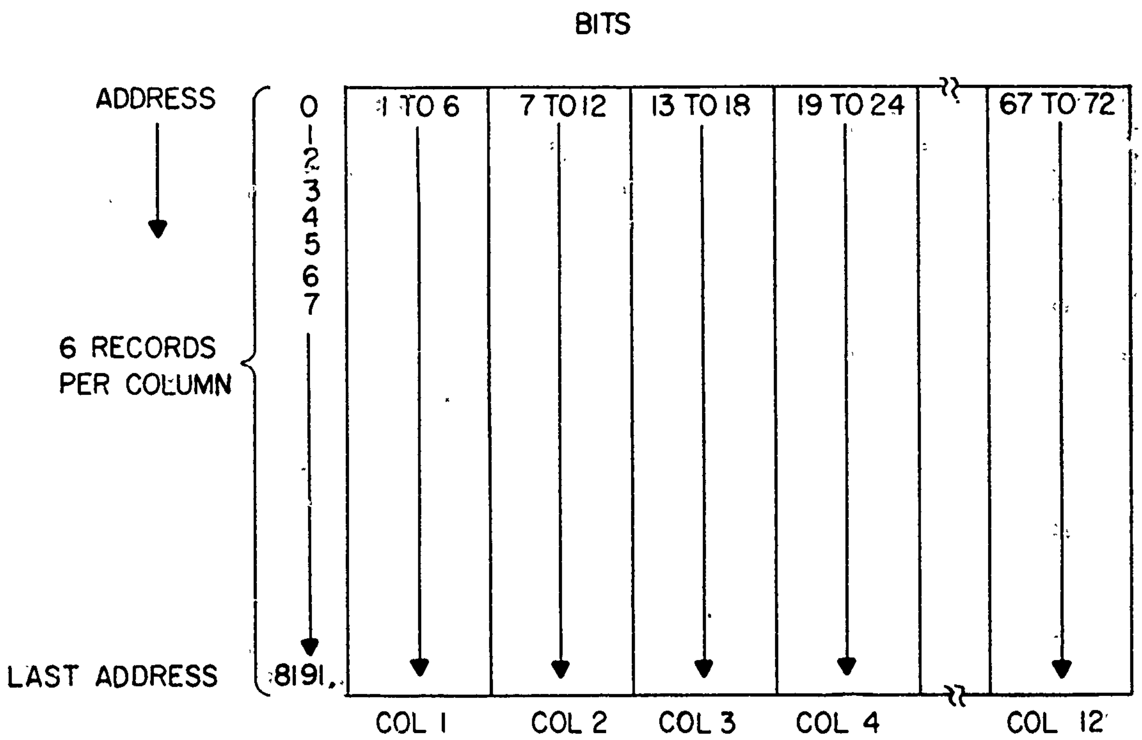
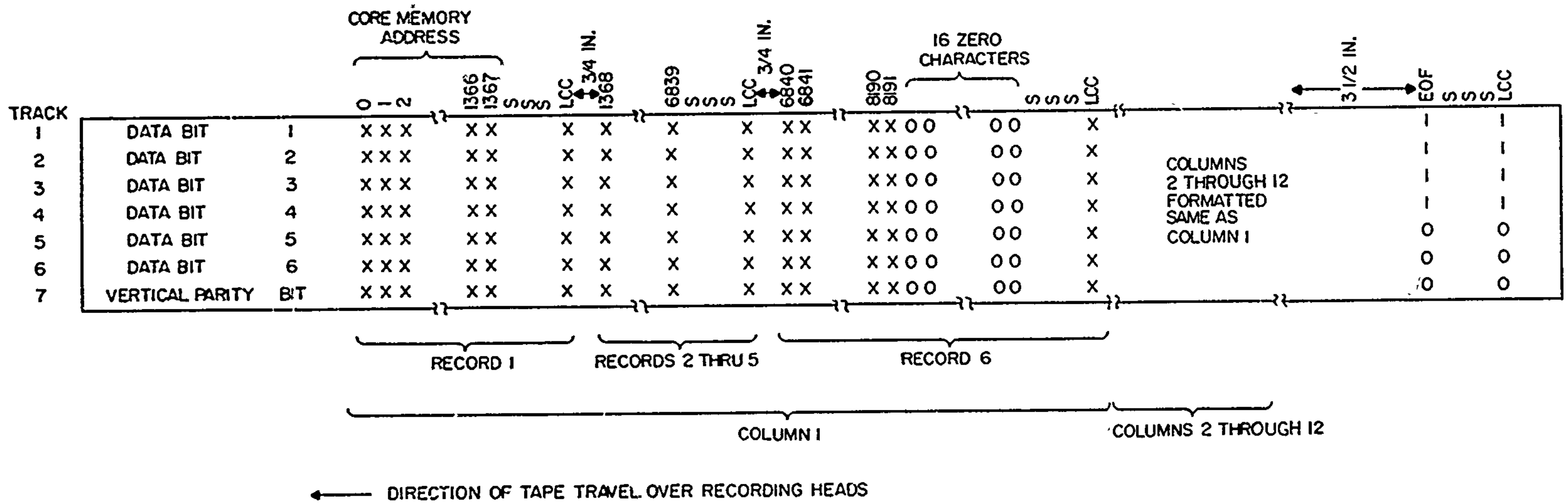


Figure 14. Column representation of the magnetic core memory for fragment velocity data

corresponding to octal 17, consists of logic 1s in tracks 1 through 4 and zeros elsewhere. Following an end-of-file code, longitudinal parity bits are recorded on each data track.

FRAGMENT DISPERSION

Fragment dispersion information is obtained as a byproduct of fragment velocity measurement by counting the number of hits per screen. If, for example, 72 sensor screens are arranged in a semicircle around the test item, each screen subtends 2.5 degrees of horizontal arc. Consequently, the data readout yields the number of hits in each 2.5-degree increment of arc. Since the data acquisition system can not detect simultaneous hits, site personnel count the number of holes in each screen. The correlation between the computer count of hits and the manual count is usually very close.



LEGEND:

EOF	END OF FILE (OCTAL 17)
LCC	LONGITUDINAL CHECK CHARACTER
S	BLANK SPACE
X	LOGIC 1 OR LOGIC ZERO

Figure 15. Digital tape format for fragment velocity data

SECTION IV

PRESSURE VELOCITY MEASUREMENT AND DATA COLLECTION

Detonation of an explosive charge creates a blast wave that moves out from the explosive at supersonic speed. A sharp pressure jump, or pressure discontinuity, marks the leading edge of the blast wave. This discontinuity is the shock front from the explosion. The VALTS measures the time of shock front travel over a known distance from the explosive to a piezoelectric crystal transducer that detects the time of arrival (TOA) of the shock front.[3]

The technique for measuring pressure velocity (shock front velocity) is the same as that for measuring fragment velocity (Figure 5); however, the signal conditioning circuits are different. Figure 16 illustrates the pressure-velocity signal-conditioning circuit. The impedance converter, mounted on the transducer stand, converts the high impedance output of the transducer into a low output impedance signal and provides sufficient drive to overcome cable loss between the test arena and the operations building. The charge amplifier has a manual gain control for setting the signal amplitude to about +4 volts which is the proper level for reading data into the magnetic core memory. After pressure velocity data are stored in the core memory, they receive the same post-mission processing as fragment velocity data.

Normally only two to six pressure velocity transducers are used on a mission because the pressure front moves from the detonated munition at a relatively uniform speed in all directions. Since it is wasteful to collect data on only two to six channels of a 72-channel system, pressure velocity data and fragment velocity data are usually collected simultaneously, in which case the number of TOA transducers plus the number of sensor screens total 72.

Pressure velocity transducers and mounts are described in Appendices II and III.

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[3] An alternate method that measures shock front travel time between two TOA transducers is discussed in Section V with the pressure profile data system. The alternate method is seldom used because it is not as accurate and reliable as the primary method.

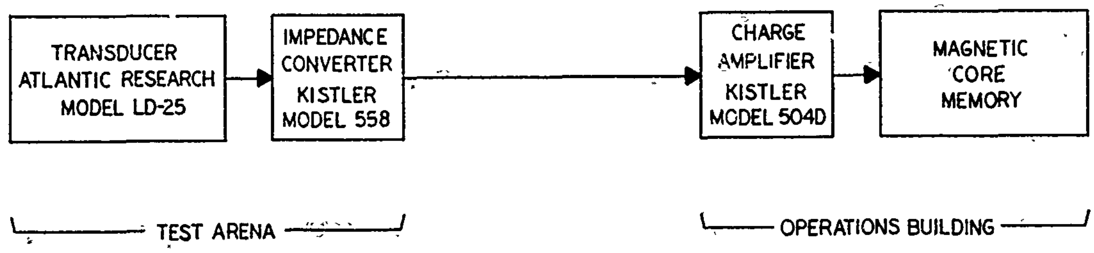

Figure 16. Block diagram of pressure velocity signal conditioning circuit

SECTION V

PRESSURE PROFILE MEASUREMENT

PURPOSE OF PRESSURE PROFILE MEASUREMENT

The blast damage potential of an explosive depends largely upon the cross-sectional area (pressure profile) of the blast wave which strikes a target. The time integral of the blast overpressure is an important parameter in the study of blast damage potential. The VALTS measures the pressure profile, expressing it in time-overpressure relations.

PRESSURE PROFILE TRANSDUCERS

The pressure profile data acquisition system, which was discussed briefly in Section II and shown in block diagram form in Figure 6, employs industrial transducers manufactured by the Kistler Corporation as the profile sensing device. One model of the transducers can measure pressures up to 5,000 psi; two other models are used with lower yield explosives to obtain finer resolution of data. (Profile transducer characteristics are discussed in Appendix III.) Regardless of model, the transducer output is an analog voltage proportional to the amplitude of the blast wave in psi.

PRESSURE PROFILE SIGNAL CONDITIONING

Low capacitance coaxial cables carry the pressure profile signals from the arena to the operations building where the signals are conditioned for analog recording on magnetic tape. Signal conditioning of the low-level transducer signal before recording is necessary to maintain the dynamic characteristics of the sensed signal. Each pressure profile data channel has a signal conditioning circuit (Figure 17). The calibration amplifier in the circuit provides a high input impedance to the pressure signal. The input impedance which is greater than 1 megohm at the highest frequency closely matches the output impedance of the transducer and limits the loading error to less than 0.01 percent.

The low-pass active filter traps frequency components generated in the transducer from the mechanical resonance of the piezoelectric crystal. The filter, having a sine wave response that is flat from dc to 120 kHz and only 3 db down at 200 kHz, has sufficient frequency response for signal pulses with rise times up to 2 microseconds.

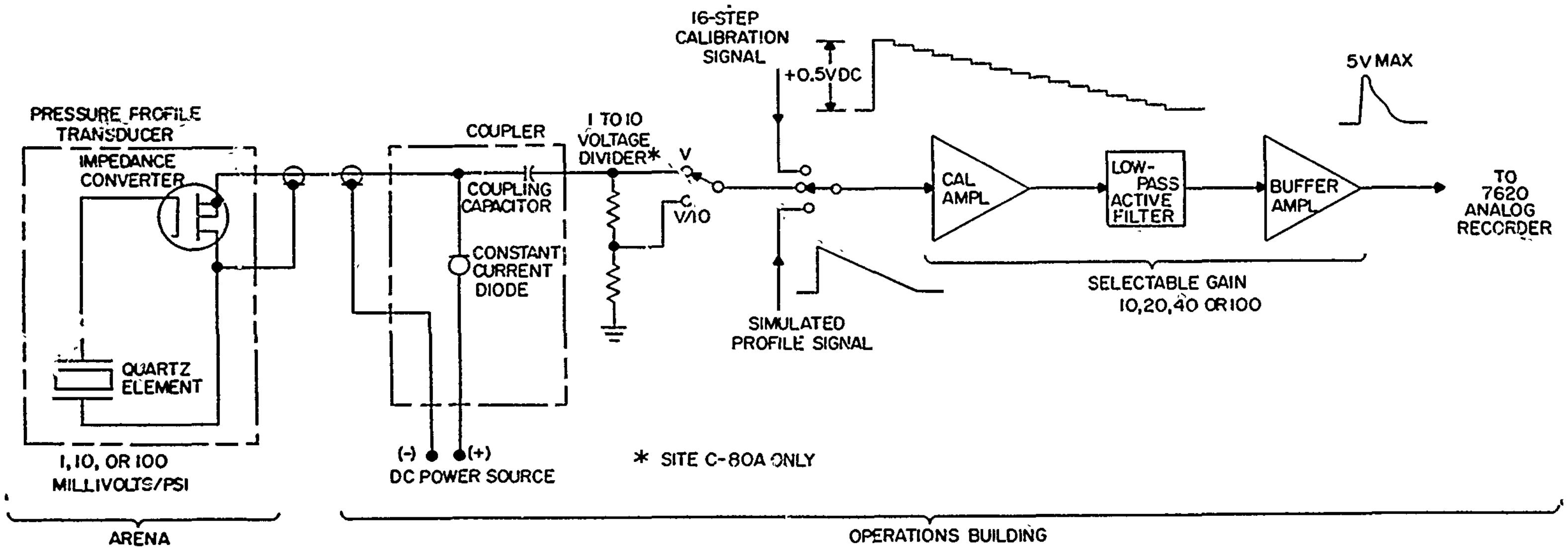

Figure 17. Block diagram of pressure profile recording channel

The buffer amplifier develops drive for the analog recorder. The output impedance of the buffer stage, which is less than 1 ohm, minimizes the loading error when driving the input circuit of the recorder.

As shown in Figure 17, a calibration signal can be injected into the signal conditioned circuit for recording on the analog tape. The calibration signal, generated by a precision digital-to-analog converter, is a 16-step voltage waveform which is injected before each mission into all the pressure profile channels simultaneously. The recorded calibration signal is processed in the same manner as profile data signals and is used in the data reduction process to calibrate the pressure profile amplitude at each data point. A simulated pressure profile signal can also be injected into the signal conditioning circuit to check system operation. The simulated signal is a linear ramp voltage.

Again referencing Figure 17, the total gain of the system from transducer to analog recorder depends upon the transducer sensitivity, the voltage divider ratio, and the gain of the amplifier stages. Profile transducers selected for the VALTS have sensitivities of 1, 10, or 100 millivolts per psi. The system can measure peak overpressures up to 5,000 psi using a transducer having a sensitivity of 1 millivolt per psi. For this measurement, the voltage divider is set to attenuate the signal by a factor of 10 to keep the peak amplitude of the sensed signal equal or less than 0.5 volt at the amplifier input. All 12 data channels at Site C-80A have a voltage divider circuit; Site C-80C does not have voltage divider circuits in its pressure profile data channels.

The choices of transducer sensitivity, voltage divider ratio, and amplifier gain can not be changed during a mission; therefore, to obtain optimum signal resolution without saturation it is necessary to make the choices before the mission, basing the choices on the expected peak overpressure from the explosive. Normally, a 25 percent safety factor is added the expected value of the overpressure.

POST-MISSION PROCESSING OF PRESSURE PROFILE DATA

After a mission is completed, the data recorded on analog tape are first digitized, coded, formatted, and gated into the magnetic core memory and then stripped from the memory onto digital tape. This process is performed one channel at a time for each data channel on the analog tape. The analog data consist of the 16-step calibration waveform, the pressure profile signal, profile velocity data, and profile duration data. Profile velocity data are not normally collected on analog tape; however, when they are not

collected, a pressure velocity word consisting of all zero data bits plus code bits is read into the core memory. Pressure duration is not recorded per se on the analog tape but is obtained indirectly from system logic circuits.

An eight-bit analog-to-digital (A/D) converter digitizes the calibration and pressure profile signals (a different process, described later, digitizes the profile velocity and profile duration data). The A/D converter digitizes the calibration signal at a 25-kHz conversion frequency; the digitizer synchronizes with each level of the 16-step signal and performs a conversion at each level. The profile signal conversion frequency is 50 kHz which provides data samples at 20-microsecond intervals. The conversion frequencies are derived from a 1.2-MHz clock. The resolution of the A/D converter is plus or minus the least significant bit (LSB); since the converter is an eight-bit unit and the range of the analog input signal is zero to 1 volt, the resolution is about +4 millivolts at the input terminals. The A/D converter operates independently, requiring only a start conversion command and an analog input. Once started, the conversion process is automatic and continuous. The A/D converter employs a successive approximation technique which compares the unknown analog input (calibration or profile signal) to the outputs of eight precision current sources that correspond to signal levels in binary sequence, 2^7, 2^6, ..., 2^0. A synchronized counting chain successively switches the outputs of the current sources to a comparator circuit. Starting with the most significant current source, eight comparisons are made and recorded in a binary register. After the last comparison is completed, the eight bits in the binary register, which represents the analog signal level, are transferred to a temporary storage register. The eight data bits in the storage register are then multiplexed with code bits into the magnetic core memory as two six-bit characters. Each six-bit character consists of four data bits and two code bits that identify the type of data.

The VALTS was originally designed to collect pressure velocity data from TOA transducers on analog tape and, for that reason, included provisions for digitizing the velocity data into a nine-bit binary word that represented the time of pressure front travel between two TOA transducers placed at different distances from the test item. A precision counter, that started counting when the pressure front arrived at the first transducer and stopped when the front reached the second transducer, developed the velocity word which was stored in a temporary storage register. Collecting pressure velocity data on analog tape is still possible but this method is seldom employed. When velocity data are not collected on analog tape, the contents of the temporary storage register, which is all zeros, are multiplexed into the magnetic core memory with code bits as three six-bit characters. Thus,

whether or not velocity data are collected on analog tape, a nine-bit velocity word is always recorded in the core memory.

Pressure duration is obtained by two crossover detectors, the first of which detects the time when the leading edge of the pressure front rises above a critical level; the second crossover detector detects the time when the trailing edge of the profile signal falls below a critical level. A counting circuit which starts and stops at the crossover points develops a binary number representing the profile duration. This number is stored in the core memory directly after the velocity data.

Table II illustrates the coding and formatting of pressure data in the core memory. Only the first six bits of memory are used. Each calibration word is divided into two six-bit characters, a character consisting of four data bits followed by two code bits. The first character of each word contains the most significant data bits. Pressure profile words are formatted into the memory in the same manner as calibration words. The pressure velocity word, because it contains nine data bits, is multiplexed into memory as three six-bit characters. The third character in the velocity word has only one data bit; therefore, three zero bits are added to fill out the character. The pressure duration word requires four six-bit characters and is formatted as shown in Table II.

PRESSURE PROFILE FORMATTING ON DIGITAL TAPE

After pressure profile data are stored in the magnetic core memory, they are stripped out of the memory onto digital tape. Transferring the data to digital tape is the second step of the post-mission processing of profile data. The formatting on digital tape records data bits on tape tracks 1 through 4, code bits on tracks 5 and 6, and a vertical parity bit on track 7. The data recorded on the tape appear in the same sequence as shown in Table II and are formatted into standard record lengths in the same manner as fragment velocity data.

Table II. Format of pressure data in core memory

Address[a]	Core memory					
	Data bits				Code bits	
	1	2	3	4	5	6
	1st calibration word					
0	2^4	2^5	2^6	2^7	0	0
1	2^0	2^1	2^2	2^3	0	0
	2nd calibration word					
2	2^4	2^5	2^6	2^7	0	0
3	2^0	2^1	2^2	2^3	0	0
	16th calibration word					
30	2^4	2^5	2^6	2^7	0	0
31	2^0	2^1	2^2	2^3	0	0
	1st pressure profile word					
32	2^4	2^5	2^6	2^7	1	0
33	2^0	2^1	2^2	2^3	1	0
	Last pressure profile word					
X	2^4	2^5	2^6	2^7	1	0
X	2^0	2^1	2^2	2^3	1	0
	Pressure velocity word					
X	2^5	2^6	2^7	2^8	0	1
X	2^1	2^2	2^3	2^4	0	1
X	0	0	0	2^0	0	1
	Pressure duration word					
X	2^9	2^{10}	2^{11}	2^{12}	1	1
X	2^5	2^6	2^7	3^8	1	1
X	2^1	2^2	2^3	2^4	1	1
X	0	0	0	2^0	1	1

[a] Address numbers denoted by X depend upon the duration of the pressure profile.

SECTION VI

SUMMARY OF FINDINGS

The VALTS is superior to other systems for statistically testing the effectiveness of explosive munitions. Tests have proven that VALTS measurements of fragment velocities are more accurate than measurements made by flash panel photographic techniques and that a higher data recovery rate is obtained using the VALTS than that obtained using the flash panel method.

The VALTS is fully electronic and is designed to collect fragment velocity, pressure front velocity, and pressure profile velocity data. In the collection process, fragment velocity data and pressure front velocity data are recorded in digital format suitable for direct entry into the CDC 6600 Computer of the Computer Sciences Laboratory. Pressure profile data, although collected in analog form, are converted, as an on-site post-mission function, into digital format for data reduction. Hence, the VALTS is completely compatible with the electronic computers of the Computer Sciences Laboratory. This feature insures rapid, accurate data reduction. In this regard, the VALTS eliminates the laborious, time-consuming manual readout of data collected on film and in doing so eliminates human errors in judgement that sometimes are made in the manual readout process.

The VALTS has a wide range of operational flexibility and versatility. Encompassing three test ranges, the system can test munitions having up to 3,000 pounds of explosive charge. With the three ranges, test arena geometry can be adjusted to fit the characteristics of the munition under test. Data sampling rates can be predetermined and set to provide optimum data collection for a specific munition. Sensor screens, since they are constructed by ADTC site personnel, can be built with window sampling areas and distances between the conducting surfaces of the screen to match the requirements of the project. Fragment velocity measurements and pressure front velocity measurements can be made simultaneously with up to 72 sensors.

The VALTS test ranges have been actively supporting test missions since 1971. During this time mission failures have been exceptionally low.

APPENDIX I

REDUCED DATA

Appendix I discusses the content and format of reduced data received from the Computer Sciences Laboratory. The complete data package includes not only reduced data but also a page containing mission identification, mission parameters, and computer program options employed in reducing the data (Figure I-1). The mission identifiers and parameters are obtained from the site log which is delivered to the Computer Sciences Laboratory with the tape. The computer options listed on the figure are used to identify to the computer the particulars of the arena configuration.

Figure I-2 illustrates the screen placement for the test. For this test, screens were placed 8 and 16 feet from the test item. Figure I-3 presents a printout of reduced data obtained from screens no. 9 through no. 12. The velocity column lists the velocity of each fragment that penetrated the screen whereas the average velocity column lists the accumulative average. To illustrate, the fourth entry in the average velocity column is the average velocity of the first four fragments that hit the screen. Velocities are expressed in feet per second. The time of arrival column gives the fragment travel time in seconds from T_0 to the time when the fragment first shorted the surfaces of the sensor screen. The location column gives the core memory address number (word location) of initial fragment detection. The time in contact column is a listing of how long each fragment shorted the screen surfaces. This column provides a rough estimate of fragment size because large fragments take more time than ll fragments in passing through a screen.

gures I-4 and I-5 present data summaries. With the exception of P (average velocity) and SD (standard deviation) the columns are self- natory.

Pressure velocity data are presented in essentially the same manner as fragment velocity data; therefore, examples of pressure velocity data are not included in the report.

Figure I-6 illustrates a machine-prepared graph of pressure profile data. The time base extends from 0 to 5 milliseconds. Data points are plotted at 20-microsecond intervals which correspond to the digitization conversion frequency of 50 kHz. The ordinate values plotted on the graph

are pressure levels of the shock wave in pounds per square inch. This graph reveals the presence of a second and a third shock wave.

The Computer Sciences Laboratory also prepares a companion graph to the pressure profile graph. The companion graph (Figure I-7) is a plot of cumulative impulse versus time. This graph is a time integration of the area beneath the pressure profile graph and provides a measure of the total effectiveness of the shock wave. A mathematical-physical interpretation of the graph is beyond the scope of this report.

```
PROJECT 8788W047    MSN 3056    1 SEPT 1971    SITE C-88A
MUNITION=FRAG MAT                        FRAGMENTATION TEST
DATA REDUCTION BY TSXBW-1                            FILE 2


INPUT TAPE =  7735

THE NUMBER OF FILES TO SKIP =  1

NUMBER OF ADDRESSES TO SKIP = -0

SWITCH ONE =       0.0000  MILSEC
SWITCH TWO =     -0.0000  MILSEC
SWITCH THREE =     -0.0000  MILSEC

CYCLE RATE ONE =    600.0000 KC
CYCLE RATE TWO =     -0.0000 KC
CYCLE RATE THREE =     -0.0000 KC

AVERAGE VELOCITIES O/P TAPE = -0
SCREEN OPTION =  -0
RADIUS OPTION =  1
COMPOSITE TAPE OPTION = -0
BAD CELLS OPTION = -0
POLAR ZONE OPTION = -0
EDIT OPTION =     -0


PROCESS FILE    2 THROUGH    2
TAPE8 OUTPUT OF EDITED DATA =    -0



REGULAR RUN
```

Figure I-1. Computer instruction data sheet

SCREEN	RADIUS	POLAR ZONE	DEGREES
1	8.00	1	0= 10
2	8.00	1	
3	8.00	1	
4	8.00	1	
5	8.00	2	10= 20
6	8.00	2	
7	8.00	2	
8	8.00	2	
9	16.00	3	20- 30
10	16.00	3	
11	16.00	3	
12	16.00	3	
13	16.00	4	30- 40
14	16.00	4	
15	16.00	4	
16	16.00	4	

Figure I-2. Computer summary of screen placement

FILE = 2 POLAR ZONE = 3 20- 30 DEGREES

SCREEN NO. 9 ZONE NO. 3

VELOCITY	TIME OF ARRIVAL	LOCATION	TIME IN CONTACT	AVE VELOCITY
3931.20	.004070	2442	.000008	3931.20
3847.70	.004158	2495	.000005	3889.45
3475.74	.004603	2762	.000008	3751.55
3431.02	.004663	2798	.000008	3671.42
3385.05	.004727	2836	.000008	3614.14
3358.99	.004763	2858	.000008	3571.62
3279.81	.004878	2927	.000005	3529.93
2471.04	.006475	3885	.000005	3397.57
2279.20	.007020	4212	.000022	3273.31
2267.36	.007057	4234	.000012	3172.71
2210.45	.007238	4343	.000012	3085.23
1632.65	.009800	5880	.000037	2964.19

SCREEN 9 DATA SYSTEM HITS = 12

SCREEN NO. 10 ZONE NO. 3

VELOCITY	TIME OF ARRIVAL	LOCATION	TIME IN CONTACT	AVE VELOCITY
4785.64	.003343	2006	.000007	4785.64
4698.97	.003405	2043	.000007	4742.31
4610.95	.003470	2082	.000012	4698.52
4584.53	.003490	2094	.000008	4670.02
4554.08	.003513	2108	.000007	4646.83
4541.15	.003523	2114	.000007	4629.22
4519.77	.003540	2124	.000005	4613.59
4473.44	.003577	2146	.000005	4596.07
4426.00	.003615	2169	.000005	4577.17
4401.65	.003635	2181	.000007	4559.62
4383.56	.003650	2190	.000005	4543.61
4369.59	.003662	2197	.000005	4529.11
4336.04	.003690	2214	.000020	4514.26
4272.36	.003745	2247	.000007	4496.98
4253.43	.003762	2257	.000005	4480.75
4229.07	.003783	2270	.000007	4465.02
4195.80	.003813	2288	.000007	4449.18
4159.45	.003847	2308	.000008	4433.08

SCREEN 10 DATA SYSTEM HITS = 18

SCREEN 11 DATA SYSTEM HITS = 0

SCREEN NO. 12 ZONE NO. 3

VELOCITY	TIME OF ARRIVAL	LOCATION	TIME IN CONTACT	AVE VELOCITY
4610.95	.003470	2082	.000005	4610.95
3692.31	.004333	2600	.000027	4151.63
3617.18	.004423	2654	.000023	3973.48

SCREEN 12 DATA SYSTEM HITS = 3

Figure I-3. Computer listing of fragment velocity

AVERAGE VEL	MAX VEL.	MIN VEL	TOTAL NO HITS	FOR SCREEN
4697.24	5429.86	4040.40	21.0	2
3750.69	4532.58	3065.13	4.0	3
3224.63	3539.82	2316.60	8.0	5
4049.01	5000.00	2250.35	29.0	6
4708.33	4733.73	4682.93	2.0	8
2964.19	3931.20	1632.65	12.0	9
4433.08	4785.64	4159.45	18.0	10
3973.48	4610.95	3617.18	3.0	12
3698.74	4678.36	1519.23	15.0	13
4687.53	5095.54	4297.22	18.0	14
4709.05	5274.73	4465.12	9.0	15
3444.60	3566.12	3244.34	5.0	16

Figure I-4. Computer summary of velocity data by screen.

POLAR ZONE	DEGREES	VBAR	VMAX	VMIN	NO OF HITS	SD
1	0- 10	4546	5430	3065	25	565.5
2	10- 20	3914	5000	2250	39	881.5
3	20- 30	3857	4786	1633	33	845.8
4	30- 40	4244	5275	1519	47	795.1

Figure I-5. Compute. summary of velocity data by polar zone

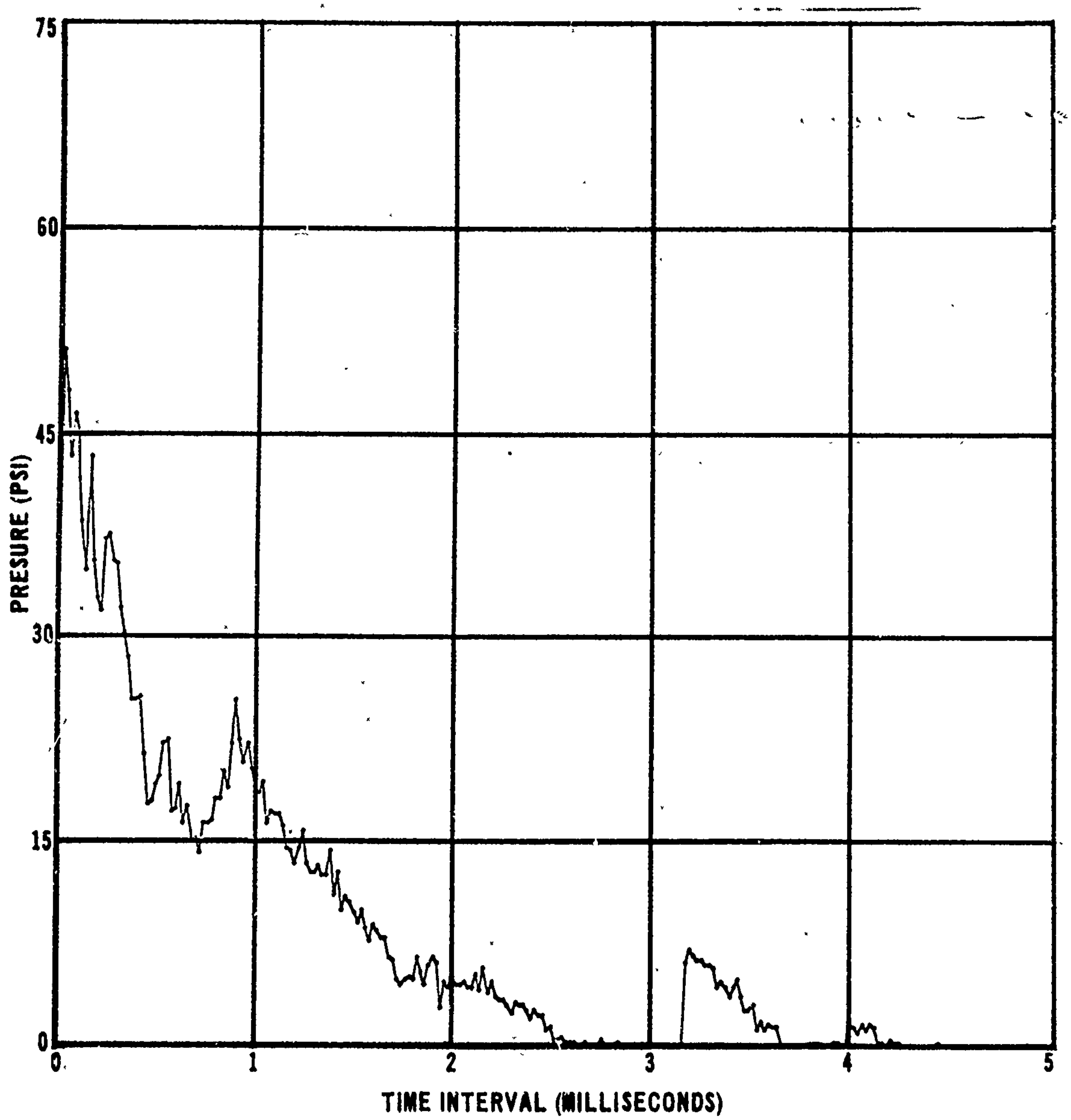

Figure I-6. Pressure profile graph

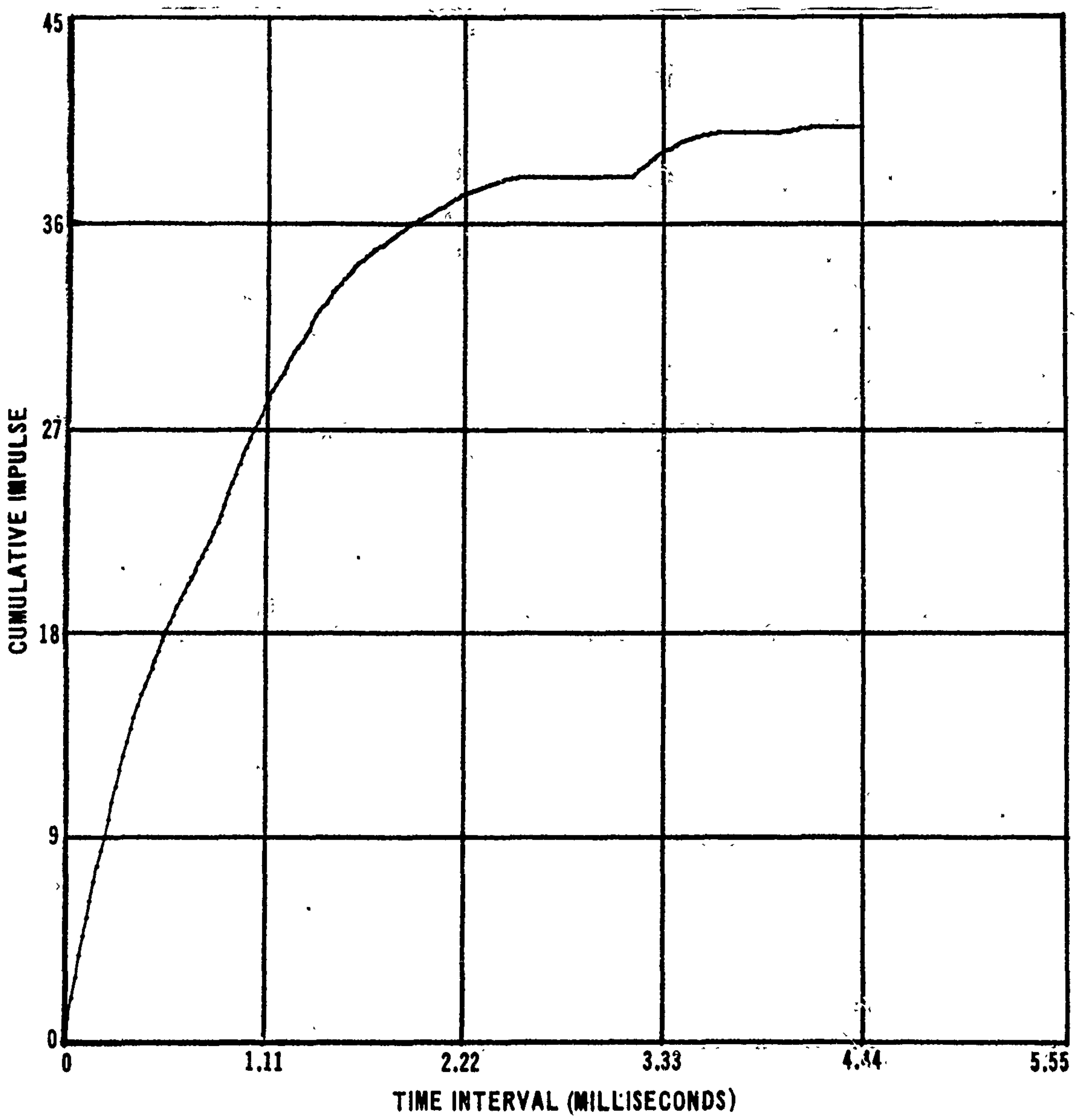

Figure I-7. Cumulative impulse graph

APPENDIX II

TRANSDUCER DESCRIPTIONS AND SPECIFICATIONS

PRESSURE VELOCITY TRANSDUCERS

The VALTS uses Atlantic Research Corporation Model LD-25 transducers to detect the time of arrival of shock waves. An unmounted LD-25 transducer is shown in Figure II-1 along with an LD-25 transducer in a transducer mount. A Kistler Model 202C pressure profile transducer is included in Figure II-1 for comparison. Manufacturer's specifications of the model LD-25 transducer are as follows:

Sensitivity	0.15 volt/psi
Sensitivity	-113 db
Charge sensitivity	35 pico coulombs/psi
Capacitance	240 picofarads
Maximum static pressure	3,000 psi
Rise time face-on	1 μsec
Polarity with positive pressure	Positive
Direct-current resistance	500 megohms
Operating temperature range	-40° to +200°F
Total weight (maximum)	0.6 oz

PRESSURE PROFILE TRANSDUCERS

The VALTS measures pressure profiles by use of Kistler Corporation Model 202C series transducers. The 202C series of transducers consists of Models 202C1, 202C2, and 202C5 which are designed to sense high, medium, and low pressure profiles respectively. Manufacturer's specifications of the 202C series follow:

Common specifications

Ground isolation	None
Linearity deviation	1 percent full scale
Vibration sensitivity	0.002 psi/G
Temperature range	-65 to +250°F
Shock, 1 ms width	2,000 G
Vibration limit	500 G
Weight	7 grams
Sealing (all welded)	Hermetic

Power supply requirements

Voltage	+22 to 30 volts dc
Current	4 ± 1 milliamperes
Ripple (maximum)	1 millivolt rms

Individual specifications

Model		202C1	202C2	202C5
Pressure range for 5 volt output (psi)		5,000	500	100
Maximum pressure (psi)		7,000	2,000	400
Sensitivity (millivolt/psi)		1.0 ± 0.05	10.0 ± 0.5	50.0 ± 10
Resolution (noise) (psi)		0.2	0.02	0.004
Resonant frequency (kHZ)		400	400	250
Thermal sensitivity shift (%/deg F)		0.04	0.04	0.04
Time constant (sec)	68°F	1,000	200	1
	250°F	50	10	0.1
Low frequency response (Hz)	68°F	0.0005	0.002	0.5
	250°F	0.01	0.04	5
Rise time, 10 to 90% (μsec)		1	1	2
Zero signal bias level (volts)		11 ± 2	11 ± 2	11 ± 2

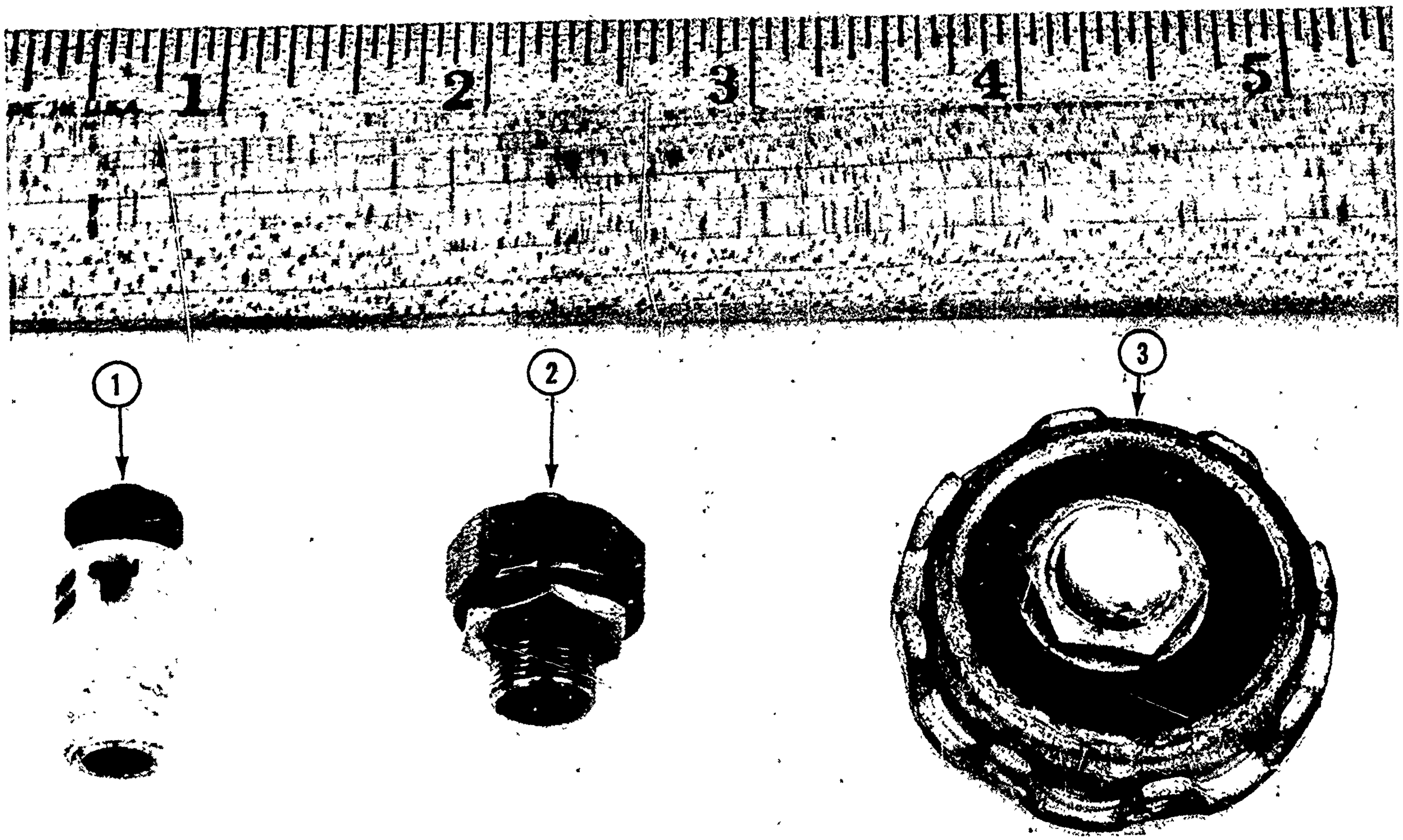

Figure II-1. Pressure transducers showing: (1) Kistler 202C pressure profile transducer, (2) Atlantic Research LD-25 pressure velocity transducer, and (3) LD-25 transducer in mount

APPENDIX III

TRANSDUCER MOUNTS AND STANDS

Figure III-1 shows a typical mount and stand for Kistler pressure profile transducers. The wedge-shaped mount, attached to a threaded pipe at the top of the stand, is aerodynamically designed to minimize distortion of the blast wave as it passes the pressure profile transducer. The transducer is recessed in the mount and covered with silicon rubber to protect it against high temperature transients. The mount and stand shown in the figure are used for making incident (side-on) pressure profile measurements; the point of the wedge faces the munition.

Occasionally, reflected (face-on) pressure profile measurements are made using a 1-foot square, 2-inch-thick steel plate as the mount. The plate, with the transducer in the center, is placed on the ground below the explosive device which is mounted in a rack several feet above the ground.

The stand shown in Figure III-1 for pressure profile transducers can also be used for pressure velocity transducers. Figure III-2 illustrates this application.

The mounts described in this appendix are obtained from Brown Engineering Corporation. The stands were constructed at the Test Area C-80 complex; other types and sizes of stands are constructed to meet various project requirements.

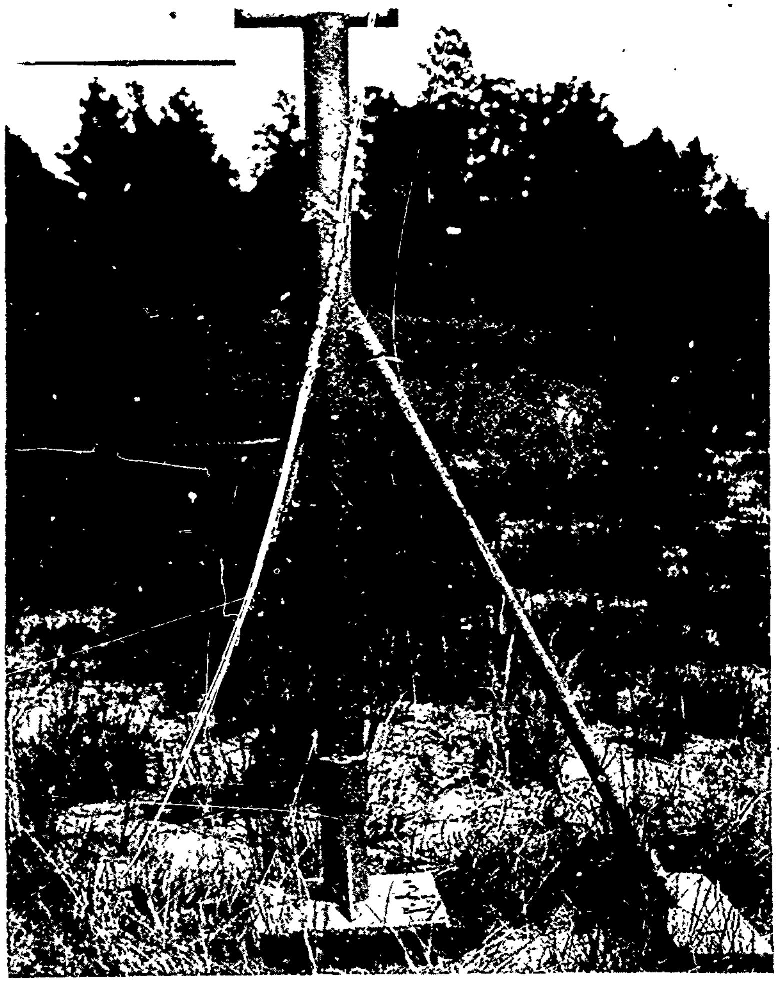

Figure III-1. Pressure profile transducer mount and stand

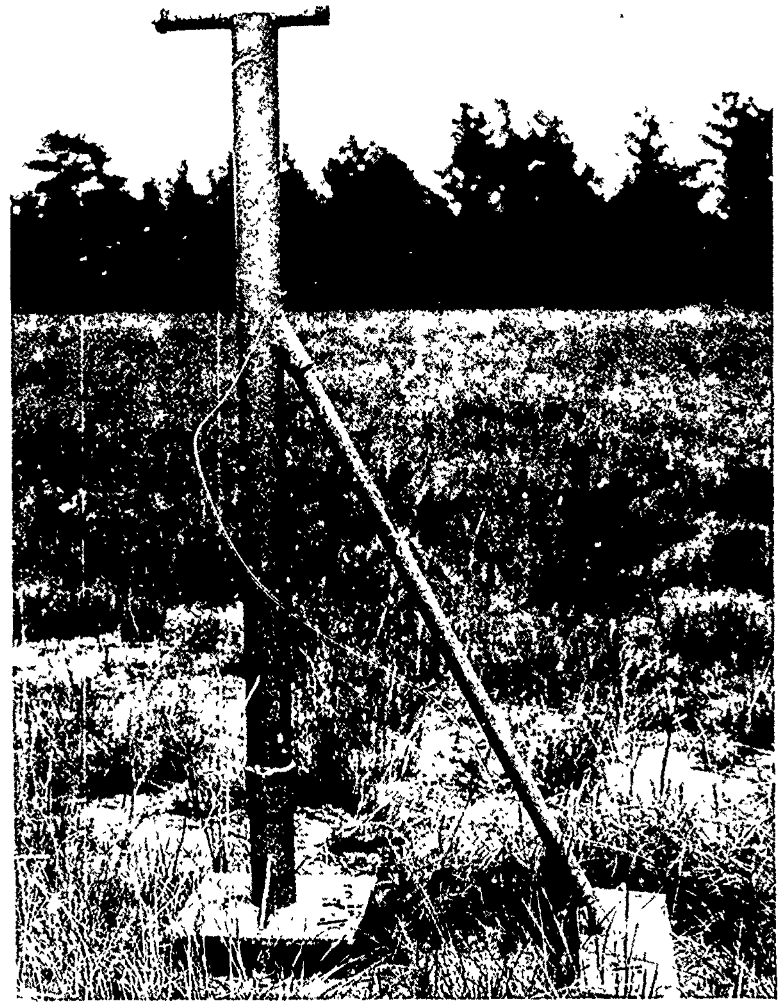

Figure III-2. Pressure velocity transducer mount and stand

APPENDIX IV

RECORDING EQUIPMENT DESCRIPTION AND SPECIFICATIONS

Figure 3 in Section II shows the four racks that house the VALTS equipment. The figures in this appendix present close-up views of individual components.

HONEYWELL MODEL 7620 ANALOG TAPE RECORDER

The Honeywell Model 7620 analog tape recorder (Figure IV-1) is a 14-channel unit of which 12 channels are data channels having ± 30 percent deviation FM electronics with a data bandwidth of 400 kHz at a tape speed of 120 inches per second. The other two channels are direct-recording channels. One direct channel functions as a servocontrol track to record the output of a highly accurate, crystal-controlled, reference oscillator. During playback, a phase lock servosystem compares the phase of the recorded reference signal to the phase of a feedback signal to provide instantaneous speed control of the tape. The other direct channel is used to record the output of a 100-kHz clock for post-mission control of the digitization conversion frequency. The analog tape recorder can accommodate reels up to 15 inches in diameter and tapes of 1-inch width. Available tape speeds are 120 and 3-3/4 inches per second.

HONEYWELL ICM-40 MAGNETIC CORE MEMORY AND MP-40 POWER SUPPLY

The magnetic core memory (Figure IV-2) is a high-speed, digital storage device capable of storing a maximum of 24 bits of information in 8,192 locations. (Each VALTS site has three core memories.) Data are stored in arrays of ferrite cores. Core selection is accomplished with three-wire, coincident current techniques. The switching time of the cores and the characteristics of the logic and driving circuit enable the memory to cycle at a rate of 1 MHz; however, as employed in the VALTS, the maximum cycling rate is 600 kHz. The memory uses monolithic integrated circuits and silicon semiconductors exclusively and includes temperature compensation of drive circuits.

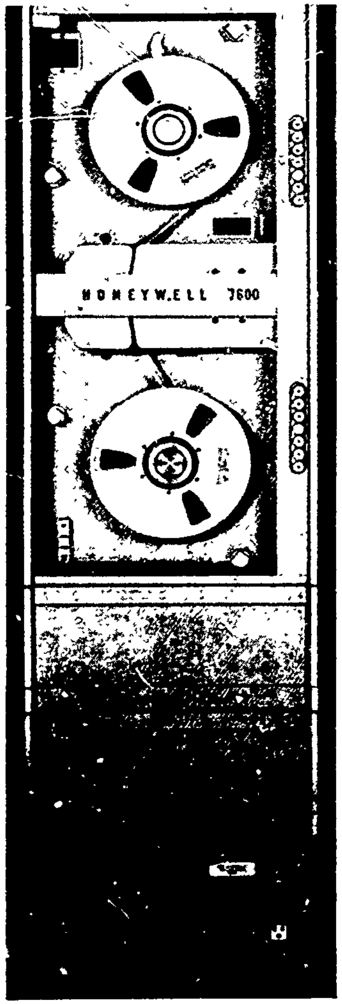

Figure IV-1. Honeywell 7600 analog recorder

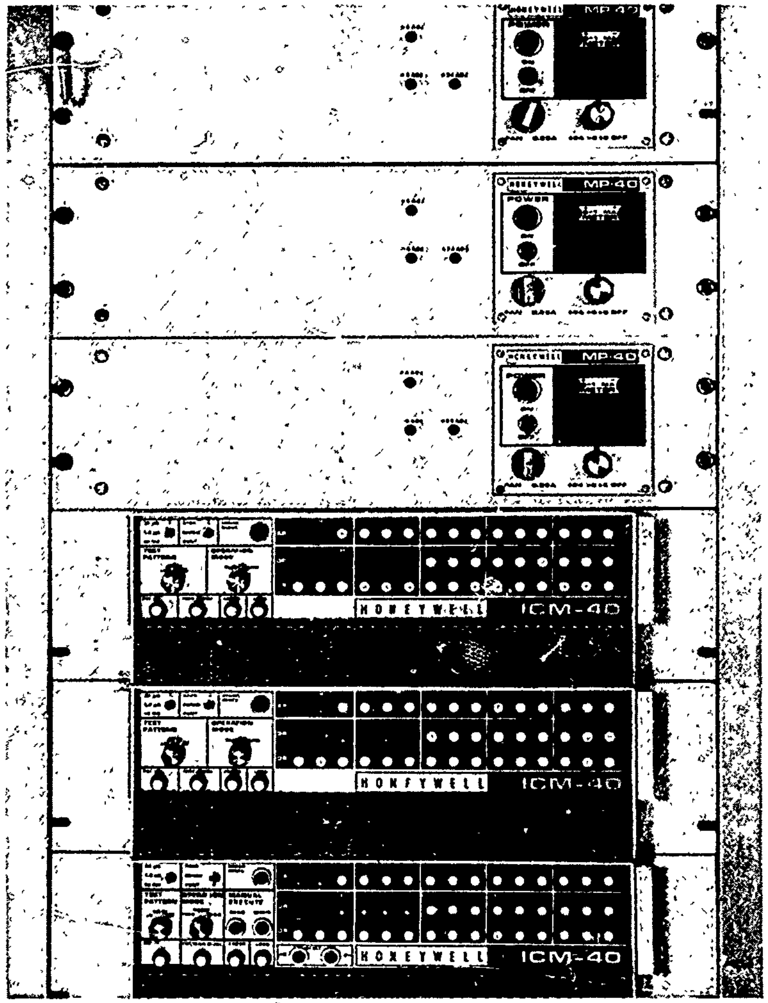

Figure IV-2. Core memories with power supplies

The MP-40 power supply (one for each magnetic core memory) supplies +28 volts dc, +6 volts dc, and -6 volts dc power to the core memory. The power supply is constructed with all-silicon semiconductors and features overload, line-transient, over-voltage, and thermal protection.

APEX TM-4 DIGITAL TAPE RECORDER

The Ampex TM-4 digital tape recorder (VALTS terminology to distinguish it from the Honeywell analog tape recorder) is a TM-4111D tape memory system comprising a TM-4 tape transport (Figure IV-3) and an 111D data electronics assembly. The tape memory system records digital data on a seven-track tape using a nonreturn to zero mark (NRZM) method of recording. Specifications of the TM-4111D tape memory system are as follows:

Tape transport	TM-4
Data electronics	111D
Data transfer speed	30 to 75 ips
Recording density	800 bpi max
Data transfer rate	60 kHz max
Number of tracks	7
System configuration	Unshared
Recording mode	NRZM
Read strobe method	OR clock
Input levels	0 and positive level (+15 volts max) 0 and negative level (-15 volts max) Bipolar (+14 and -15 volts max)
Output levels	-12 volts false 0 volt true
Operating environment	
Ambient air temperature	+50°F to +90°F
Relative humidity	40% to 70%
Altitude	0 to 7,000 feet
Nonoperating environmert	
Ambient air temperature	-20°F to +150°F
Relative humidity (no condensation)	0% to 95%
Altitude	0 to 40,000 feet

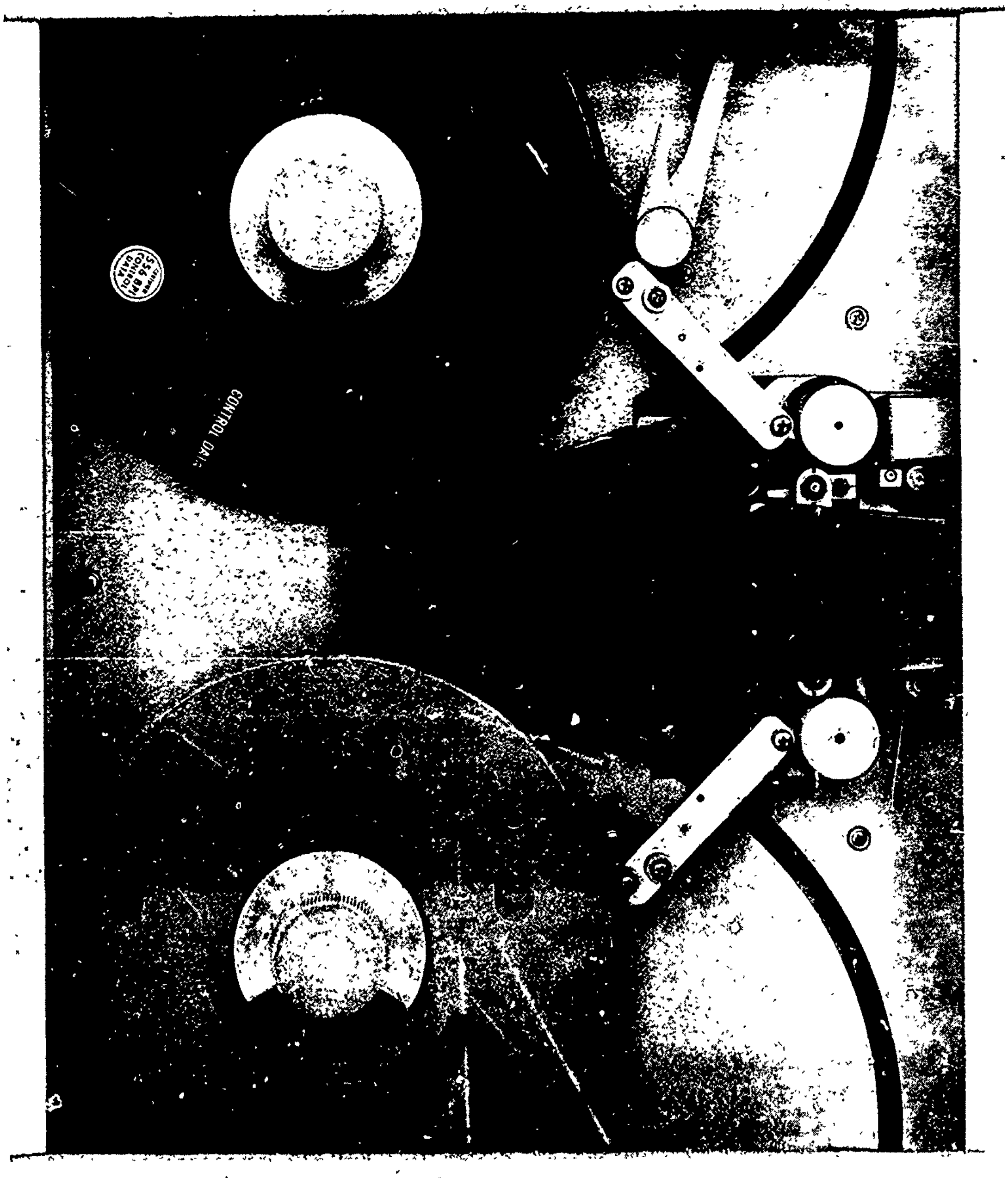

Figure IV-3. Digital tape transport

RECORDING OSCILLOGRAPH

Sites C-80A and C-80C are equipped with a 12-channel recording oscillograph for post-mission quick-look review of pressure profiles collected on the analog tape. The recording oscillograph is a Model CEC-124A manufactured by Consolidated Electrodynamics Corporation. The instrument has a mercury arc lamp whose light reflects from 12 galvanometer-driven mirrors through a simple optical system onto moving photographic paper. Each galvanometer moves in response to the pressure profile signal recorded on one of the 12 data channels of the analog tape. Although 12 signals can be recorded simultaneously on the oscillograph, usually not more than eight are recorded at a time to obtain a wider amplitude display of the signals.

Each channel of the oscillograph has a low-gain, wideband dc amplifier (10 kHz) to drive its galvanometer. The galvanometers (CEC Model 7-361) have a flat frequency response up to 5 kHz. The chart drive has selectable speeds of 0.25, 1, 4, 16, and 64 inches per second. The recording oscillograph sequentially interrupts the traces to provide an easy method of trace identification. An electronic flash timing system prints full-width timing lines across the chart at switch-selectable intervals of 0.01, 0.1, or 1 second. Figure IV-4 presents the recording oscillograph and its two galvanometer-driven amplifiers.

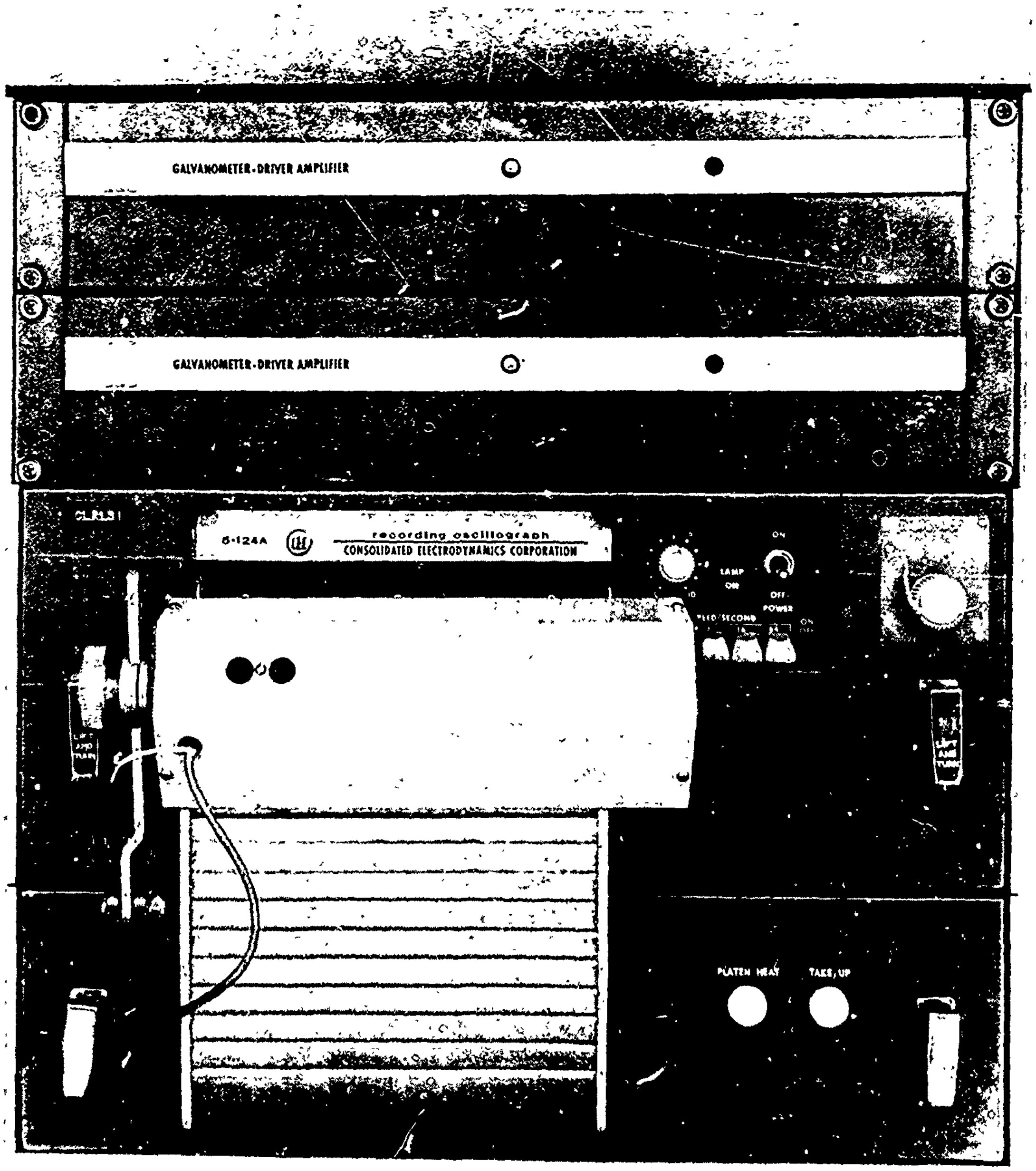

Figure IV-4. Recording oscillograph with galvanometer-driver amplifiers

APPENDIX V

BLIND-TIME CONSIDERATIONS

When two or more fragments penetrate a sensor screen simultaneously, the VALTS scores the multiple penetrations as a single hit. The system reacts to only one of the fragments which masks the presence of the others. The masking time, normally called blind time, consists of (1) the time that the masking fragment remains in contact with the conducting surfaces of the screen, (2) the signal decay time which, as discussed in Section II, is about 5 microseconds, and (3) one cycling interval of the magnetic core memory. The first factor, contact time, is determined by the fragment dimension making contact with the screen surfaces, the velocity of the fragment, and the distance between the screen surfaces. For example, a 1/2-inch fragment penetrating a 1-8-inch screen at 5,000 feet per second would maintain contact about 4 microseconds. The second factor, decay time, is constant for all fragments; during the 5 microseconds of decay time, the system logic circuits can not reset and, consequently, continue to record logic 1 data bits into memory. The third factor contributing to blind time is that the system requires one cycling period of the core memory for resetting the input flip-flop to the memory after the decay time has elapsed. To illustrate the example cited above, assume that the memory cycled at 1.67-microsecond intervals when the fragment hit the screen. Thus, the total blind time for the three factors is 10.67 microseconds.

Blind time could be reduced by shortening the decay time of the sensed fragment velocity signal; however, shortening the decay time would increase the probability of erroneously recording multiple fragment velocities from a single irregularly shaped fragment. Thus the 5-microsecond decay time is a compromise.

Blind time and methods to reduce it have been and continue to be investigated. Shock Hydrodynamics, Incorporated, in a report entitled, "Feasibility Study Lethality and Vulnerability Test Facility," November 1966, discusses some of the aspects and problems of blind time. The following is quoted from page 45 of the report:

"While simultaneous impacts, coincident impacts and impacts on the same grid elements will be missed, proper selection of the location to assure reasonably low fragment impact densities and spreads in time of arrival consistent with the circuit recovery characteristics become readily possible. The proper selection involves moving the time of arrival

detectors (sensor screens) far enough away to keep the fragment impact densities for example to less than 1 fragment per 10 square inches based upon average fragment number estimates. The greater the distance from the source, the greater also the spread in times of arrival, for a given velocity spread. Hence a design criterion for the time-of-arrival circuit, which can be deduced, is based upon the ability to resolve differences of ± 1% in velocity. Such requirements affect time-of-arrival resolution, Thus, suppose the minimum resolution time for successive fragments on the same screen should be less than a specified time, e.g., 5 x 10 -4 seconds. In this specific case if V1 = 2000 ft/sec and the distance to the screen is 100 ft., the time of flight is 50 milliseconds. V2 would have to be 2000 ± 20 ft/sec to arrive just within the resolution limits of 5 x 10 -4 seconds."

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13. ABSTRACT

This report describes the Vulnerability and Lethality Testing System (VALTS) at the Armament Development and Test Center, Eglin Air Force Base, Florida. The VALTS is a fully electronic, high-speed automatic data acquisition system for measuring fragment velocities, fragment dispersion, blast pressure-front velocities, and pressure profiles resulting from statically detonated explosives. The system collects a large quantity of accurately measured data thus substantially reducing the number of test missions required to evaluate the effectiveness of munitions. The VALTS data are reduced in the Center Computer Sciences Laboratory by means of a CDC 6600 computer and ancillary equipment. Three test sites on the Eglin reservation contain VALTS equipment. This report contains a technical description of the VALTS equipment and the techniques employed in data collection.

14. KEY WORDS	LINK A		LINK B		LINK C	
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Pressure profile						
High Explosives Test Facilities						